# REPORT RESUMES

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# EFFECT OF VARIED PRESENTATIONS OF LABORATORY EXERCISES WITHIN PROGRAMED MATERIALS ON SPECIFIC INTELLECTUAL FACTORS OF SCIENCE PROBLEM SOLVING BEHAVIOR.

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DESCRIPTORS- LEARNING LABORATORIES, SCIENCE LABORATORIES, *PROGRAMED INSTRUCTION, PRODUCTIVE THINKING, *PROBLEM SOLVING, STIMULUS BEHAVIOR, *MOTIVATION, *SCIENCE EDUCATION, *TEST CONSTRUCTION, JUNIOR HIGH SCHOOLS, LINEAR PROGRAMING, BROCKPORT, NEW YORK, STRUCTURE OF INTELLECT (SI)

THIS RESEARCH ATTEMPTED TO DEMONSTRATE THE FEASIBILITY OF DEVELOPING TEST INSTRUMENTS TO DETECT HOW LIMITED VARIABLES IN EDUCATIONAL EXPERIENCES AFFECT STUDENT BEHAVIORAL DEVELOPMENT. THE EXPERIMENTAL HYPOTHESES DEVELOPED FOR THE STUDY WERE CONCERNED WITH IDENTIFYING AND DEFINING INDIVIDUAL ABILITIES OPERATING IN THE REALM OF SCIENCE EDUCATION. JUNIOR HIGH SCHOOL STUDENT INVOLVEMENT WAS EFFECTED THROUGH THE USE OF PROGRAMED INSTRUCTIONAL MATERIALS. A 700-FRAME LINEAR PROGRAM DESIGNED TO PROMOTE UNDERSTANDING OF PHYSICAL SCIENCE PRINCIPLES WAS ADMINISTERED TO 245 EIGHTH-GRADE STUDENTS. AN ANALYSIS OF COVARIANCE WAS USED TO STATISTICALLY EVALUATE SCORES FROM THREE FACTOR-PURE TESTS, WITH STANDARDIZED READING TEST SCORES BEING USED AS CONTROL VARIABLES. TWO TESTS, A SCIENCE VOCABULARY TEST AND A SEEING SCIENCE DEFICIENCIES TEST, WERE WITHIN THE "STRUCTURE OF INTELLECT" (SI) FRAMEWORK. THE THIRD TEST WAS A NONVERBAL SCIENCE PROBLEM-SOLVING TEST WHICH PRESENTED ALL VIOLATIONS OF SCIENTIFIC PRINCIPLES IN PICTURE FORM. IT WAS CONCLUDED THAT (1) CONTENT-ORIENTED FACTOR-PURE TESTS CAN BE DEVELOPED TO EFFECTIVELY MEASURE EFFECTS OF EDUCATIONAL EXPERIENCE, (2) ACTIVE PARTICIPATION IN EXPERIMENTS SUPPORTING SCIENTIFIC PRINCIPLES IS SUPERIOR FOR DEVELOPMENT OF AT LEAST ONE PHASE OF NONVERBAL PROBLEM-SOLVING ABILITY, AND (3) THE USE OF SUPPLEMENTARY ACTIVITIES ACCOMPANYING PROGRAMED LEARNING MATERIALS PROVIDED JUNIOR HIGH SCHOOL STUDENTS WITH AN EFFECTIVE LEARNING PROGRAM. (GD)

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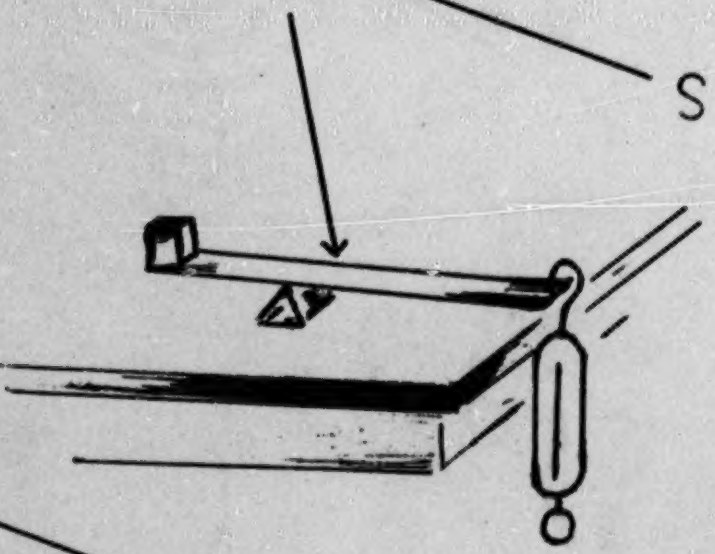
by

Donald Nasca



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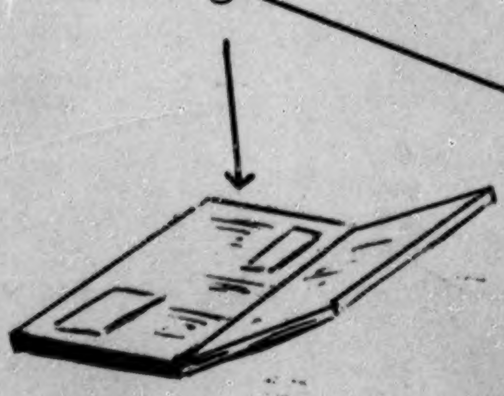
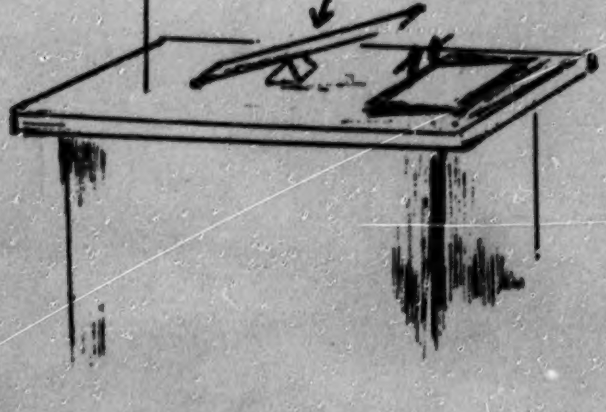


*State University College at Brockport*
*Brockport, New York*
*December 31, 1965*



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As an ex-teacher acquainted with the numerous pressures and burdens introduced by time consuming activities above and beyond those imposed by course requirements, this investigator is especially appreciative of the time and effort afforded this project by classroom teachers in the area. Not only were one to three class periods thoughtfully provided for test validation sessions and phase I data collection but some of the following teachers made further contributions through criticisms of the actual test instruments.

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Barker, New York

Mr. Leo Dumke
Attica Central School
Attica, New York

Mr. David Johnson
Canandaigua Jr. Academy
Canandaigua, New York

Mr. Thomas E. Rider
Alexander Central School
District #2

Mrs. Lenore Silberman
Brighton High School
Rochester, New York

Mrs. Doris Tondat
Brighton High School
Rochester, New York

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Wayne Central
Ontario Central, New York

Mr. James Canali
Victor Central School
Victor, New York

Mr. George Hansen
Kendall Central School
Kendall, New York

Mr. Herbert Koenig
Royalton-Hartland Central
Middleport, New York

Mr. Charles Matchett
Palmyra-Macedon Jr.-Sr. High
Palmyra, New York

| | |
|---|---|
| Mr. Frank Reddout<br>Newark Jr. High<br>Newark, New York | Mr. Authur Winiechi<br>Clarence Jr. High<br>Clarence, New York |
| Miss. Unice<br>Marion Central<br>Marion, New York | Mr. Carl Wolf<br>Letchworth Central School<br>Gainsville, New York |

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# CHAPTER I

> "I see nobody on the road," said Alice. "I only wish I had such eyes," the King remarked in a fretful tone. "To be able to see Nobody! And at that distance too! Why, it's as much as I can do to see real people, by this light!"

## INTRODUCTION

It was inferred from a recently completed research project (Nasca, 1964) that different educational experiences produced effects that could not be differintiated by broad criterion instruments. Two standardized instruments used in this earlier study indicated that two different kinds of experiences were each superior, depending upon the specific instrument being used to evaluate performance. It was concluded that this could easily be true if each of the instruments was measuring something different. Thus, different experimental treatments; in this case, methods of teaching science, could each be superior in promoting different types of behavioral development. This is not to imply that gross differences commonly perscribed or found in lab versus lecture comparisons are being considered. Rather, the more subtle intellectual abilities as outlined in the "Structure of Intellect" (Guilford 1960), are apparently operating.

### Problem

The problem may be broadly defined in terms of independent pupil abilities and effects of various experiences in gaining knowledge about science. More specifically, the question being asked is, "What individual pupil abilities are developed as a result of exposure to programed materials accompanied by related experiences supporting the scientific principles presented in the program?"

Solution of this problem thus becomes a two step process with identification of individual abilities and construction of instruments designed to measure these abilities preceding the use of these instruments in evaluating behavior resulting from exposure to experimental variables.

It has been necessary to first arrive at those independent abilities most likely to be effected as a result of exposure to the experimental treatments in use. The, "Structure of Intellect", (Guilford, 1960) model was used as a theoritical base for identifying these abilities.

The experimental hypotheses developed for the study are concerned with identifying and defining individual abilities operating in the realm of science and a comparison of the effect of three methods ob obtaining scientific information on each of the abilities. Hypotheses for the two phases of the experiment are as follows:

Phase I

1. Eighth Grade students possess four independent abilities associated with solving problems in science. These abilities may be isolated and defined.
2. The independent abilities possessed by eighth grade students may be measured by paper and pencil tests.

Phase II

1. Participation in science activities will produce higher scores on a non-verbal measure designed to evaluate sensitivity to problems than will reading about or observing those activities.
2. Participation in science activities will produce higher scores on a verbal measure designed to evaluate sensitivity to problems.
3. Participation in science activities will produce higher scores on a vocabulary test.
4. Participation in science activities will produce higher scores on a non-verbal measure designed to evaluate ability to orient oneself to changes in three dimensional space.

The null hypothesis in Phase II to be evaluated by statistical procedures include:

1. There is no statistically significant difference between participation in science activities on a non-verbal measure designed to evaluate sensitivity to problems than reading about or observing those activities.
2. There is no statistically significant difference between participation in science activities on a verbal measure designed to evaluate sensitivity to problems than reading about or observing those activities.
3. There is no statistically significant difference between participation in science activities on a vocabulary test measure designed to evaluate sensitivity to problems than reading about or observing those activities.

4. There is no statistically significant difference between participation in science activities on a non-verbal measure designed to evaluate abilities to orient oneself to change in three dimensional space than reading about or observing those activities.

## Overview

This study attempts to determine how active involvement in learning scientific principles influences some very specific student abilities. Junior high student involvement is assured through use of programed instructional materials accompanied by three methods of acquiring scientific evidence supporting the principles developed in the program. Thus, method of acquiring supporting evidence becomes the experimental or independent variable of the study. The three methods of presenting supplementary evidence include: (1) active performance in seventy-three science activities, (2) reading about the seventy-three activities, or (3) seeing a teacher demonstrate the seventy-three activities. The specific student abilities being evaluated have been arrived at through an examination of a variety of tasks that might possibly result from the learning sequence being used. Verification of the specific individual abilities selected was then arrived at through factor analytic procedures.

Approximately 360 students in twelve randomally selected 8th grade classes participated in the experimental treatment. Four eighth grade classes were exposed to each experimental treatment. Student performance resulting from participation in experimental treatments was evaluated by means of tests developed to define individual student abilities defined in Phase I. Final test scores were treated with a covariance analysis using reading as the control variable.

## Significance

It is anticipated that an approach using highly specific criterion instruments will aid in identifying how various forms of participation enhance the behavioral development of eighth grade students. The standardized test instruments normally used in such studies apparently tend to evaluate a multitude of abilities. It is highly probable that each and every experimental treatment and/or independent variable being used in many studies have promoted development of a variety of independent student abilities. The net effect of broad criterion instruments, however, shows all treatments or variables as having produced the same effect on all students. Each treatment has more probably produced specific gains which have not been differentiated by the instrument. The non-significant differences thus

**reported are non-significant only to the extent that criterion instruments have failed to take into account independent individual abilities. It is the development and use of highly selective differentiating instruments to measure individual abilities resulting from exposure to programed materials and supporting evidence that makes this a unique project.**

# CHAPTER II

> "Well, in out country," said Alice, still panting a little, "you'd generally get to somewhere else--if you ran very fast for a long time as we've been doing."
>
> "A slow sort of country!" said the Queen. "Now, here, you see, it takes all the running you can do to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!"

## BACKGROUND

### Methods and Goals of Science

To report individually on all relevant research would keep us running--but not nearly fast enough to "...get somewhere else". Experiences used to promote desirable behaviors in the area of science have been evaluated in a variety of studies. Thorough reviews of these studies are presented in Cummingham, 1946, Buck and Mallinson, 1954; Smith and Anderson, 1960; Nasca, 1964; several issues of the Review of Educational Research; and Yearbooks of the National Society for the Study of Education.

Definitions of the nature of desirable behaviors in science have frequently been put forth but as Smith and Anderson (1960, p. 1220) have pointed out "...less effort seems to have gone into attempts to relate the objectives to classroom practices in a realistic manner." One reason for this lack of articulation is that definitions frequently tended to vary. Probably the most illuminating and significant statement, for our current purpose, was made by Hurd (1961, p. 59) when he wrote "At higher levels of achievement the student should be able to establish relationships from his findings and in turn make predictions about future observations."

Beyond stating that most of the methods thus far tried can produce acceptable retentive abilities and that a laboratory method is superior for developing laboratory skills, the above references cite little progress in the field. Advances in identifying specific processes involved in developing desired competencies in science are still needed and tachniques for teaching these isolated behaviors require investigation.

Two primary reasons have been advanced to account for the lack of progress in identifying contributory factors for the development of appropiate scientific behaviors. The first, dissatisfaction with the procedures used in a majority of studies reported, is evident from the comments of Anderson and Smith. Anderson (1954) states, "There is a tendency to give far too little attention to the validity of procedures and evaluation instruments." Smith (1955) adds, " A dearth of controlled, statistically analyzed research was apparent and disconcerting." This general evaluation of science education research is voiced again in 1960 by Smith and Anderson In Encyclopedia of Educational Research (1960). They conclude that "In many instances, the studies in science education have failed to yield significant results becuase the criterion measures or examinations used have been invalid or unrealistic or have failed to sample adequately the skills or understandings under study."

A second major difficulty involves a definition of problem solving as a definite behavior resulting from science instruction. Guilford (1960) has found that the prevailing concept of problem solving is inadequate and that its frequent designation as an isolated identifiable skill is meaningless. He states that no general problem solving factor has yet been found and suggests that problem solving is as broad as behavior itself. He further points out that component aspects of problem solving behavior can be identified in the total 'Structure of Intellect' (SI) pattern. It would thus appear that the meaningless label of 'problem solving', attached to the variety of specific tasks thus far investigated could account for the inconsistent and non-significant results so frequently found by Anderson (1954), Smith (1955), and Boeck (1956). Both Guilford (1959) as a psychologist and Boeck (1956) as a science educator stress that modifications in current practices are required if further advances are to be achieved in understanding and promoting the so-called higher level process of problem solving.

## Programed Learning

Programed learning is a self instructional method of shaping verbal behavior. Although a variety of variations exist, the primary technique for achieving such behavioral changes is through student responses to a series of statements. The statements are so arranged as to provide very little chance for errors in the responses made. Initial statements in any sequence require responses that are extremely likely to be within the background of subjects in the population for whom the sequence is designed. Succeding statements then add information or stimulus elements and increases the complexity of responses. Correct responses are reinforced and the likelihood of that stimulus response reoccuring is increased. Highly specific types of verbal behavior may be developed by carefully controlling the stimulus elements presented in any given sequence.

The 'program', as the programed sequence is called, may be accompanied by a variety of materials supporting the verbal behavior being developed. Statements within the program may be used to direct subjects to participate in any number of activities not directly a part of the sequence. In this manner, concrete materials may be used in support of verbalizations being presented in the program. Very little research utilizing such supplementary procedures has been conducted and nothing appropiate for inclusion in this report is available.

It is interesting to note that early research endeavors did little more than compare programed learning with traditional classroom situations. However as McDonald (1964) points out "It is no longer fashionable to compare programed courses with conventional arrangements. Earlier attempts by educational researchers to compare programed instruction with other procedures were rarely clear about why the comparison ought to be made."

Literature on the technical aspects of programing to maximize the efficiency of a program may be broadly subdivided into two categories. One finds that earlier recommendations were derived from theoretical deductions while the second category, experimental evidence, appears more frequently in recent publications.

Holland (1961) suggested that efficient programing provides an opportunity for students to construct responses which are immediately reinforced. He states further "A third important principle is the gradual progression to establish complex repertories." Lumsdaine's (1960) three important properties of programed materials include provision for continuous active responses, immediate knowledge of results, and individualized rate of progress. Finn (1960) states that the most popular programing principles require that materials be presented in small, discrete steps. Blyth (1961) in approaching basic principles from a standpoint of practical classroom situations arrives at the same general principles of active responding, immediate feedback and small steps. These suggestions, derived from condiserations based on Skinner's thoery of operant conditioning have not necessarily been corroborated by empirical evidence.

## Step Size

Coulson and Silberman (1961) found significantly better performance, on their criterion instrument, resulting from small steps but reported that a longer period of time was required to progress through the program with smaller steps. Maccoby and Schffield (reported in Schramm, 1961) obtained their best results with a program suing short steps, gradually lengthened as students progressed through the program. Evans, Glaser, and Homme (1960) reported significantly better immediate test performance and better retention with programs using smaller steps. Shay (1961) in a study involving fourth grade students found no relationship between intelligence and step size in so far as his criterion measures could reflect such a difference.

Small amounts of information presented in each frame is apparently the most efficient procedure for all students. However, it is still questionable whether increased performance is due to actual step size or increased time that allows for a greater amount of practice time within the program.

## Response Mode

Neither Coulson and Silberman (1960) or Fry (1960) could find differences on criterion measures that could be attributed to constructed responses when compared with selected responses. Stolurow and Walker (1962) and Lamber, Miller, and Wiley (1962) both used immediate and delayed retention measures but found no significant difference resulting from overt versus convert responding groups. Hough (1962) found no difference in constructed, selected or combination of response modes. Krumboltz and Weisman (1962) found that overt responses produced better results on delayed retention tests than did covert responses. Their immediate test results are in complete agreement with other studies reported.

From evidence currently available it may be concluded that overt responding may have some beneficial, long term effect but that such an effect is not immediately apparent. However, there is a possibility that response mode should not be investigated as an isolated factor but rather in conjunction with prompting and confirmation procedures. If this is true, then current research attempting to investigate interactions of several factors may produce clearly identifiable patterns. It is also possible that in the studies thus far reported, the short sequences (all but one contained less than 150 frames) have built in motivating factors that insure active involvment irrespective of the response mode.

## Reinforcement

An apparent contradiction of confirmation acting as an immediate reinforcer is presented in a review of research by Schramm (1962a). Empirical evidence indicates that a correct response by the learner, before progression to the next frame, is of prime importance.

Prompting (clue to the correct response prior to the response) and fading (gradual withdrawal of prompts) appears to produce increased performance on criterion measures. These techniques have been compared with confirmation (reinforcement) procedures and appear to produce significantly superior results. However, it appears that such results are dependent upon the specific task as well as desired products.

Even though immediate knowledge of results has been withheld, the confirmation generally obtained in succeeding frames of a linear program has not been controlled. It is therefore possible to gain knowledge of results in an indirect manner. Because of the nature of the linear program and its ability to slowly increase competencies, it is also possible to conclude that frames are often so easy that the response is relatively well known and needs no further confirmation or that interactions, of cueing, prompting and confirmation provide the dominating influences.

## Format

Relevant research indicating a preference for a particular method of combining activities with actual programed material is lacking. Recommendations by some authors concerned with panels consisting of diagrams, maps, and/or blocks of information indicate that such inclusions can be inserted almost anywhere in the program (Finn, 1960).

An overwhelming majority of studies reviewed used the linear or extrinsic program as the primary experimental treatment. This observation tends to support the conclusion (Schramm, 1962a) that the linear program has achieved somewhat more popularity than the branching or extrinsic form introduced by Crowder.

The theoretical basis of the linear program indicates a need for active responding by each individual, immediate confirmation of the response and progression to terminal behaviors via small blocks of information. A majority of the studies reported in this review as well as those reviews by Schramm (1961b) and Ryan (1964) indicated that programs developed in this manner have produced significant changes in student behavior at all levels of learning and in a wide variety of areas. A preponderance of evidence from these studies also indicates that when compared with 'conventional techniques', programed materials consistently produce equivalent performance in shorter periods of time.

The review indicates that there is considerable emperical evidence to support the construction of programed materials with which to develop desired student behaviors. The evidence supports a linear fixed sequence program with small steps, requiring constructed responses followed by immediate confirmation. The specific program used in this investigation was constructed accordingly. It was in booklet form, with a vertical format and was logically sequenced. Although the superiority of each internal factor as well as the overall combination of relevant factors has not been established at this time, it appears that such a program will produce results equivalent to any of the forms considered.

# CHAPTER III

> "Of course they answer to their names?" the Gnat remarked carelessly.
>
> "I never knew them do it."
>
> "What's the use of their having names," the Gnat said, "if they wo'n't answer to them?"
>
> "No use to them," said Alice; "but it's useful to the people that name them, I suppose. If not,why do things have names at all?"

## PROCEDURE

### Phase I

Although the ability factors under investigation occasionally fail to respond to their names, as with Alice, naming them may be useful to the people doing the naming.

The initial part of this research project was concerned with identifying individual junior high student abilities and constructing instruments designed to measure these abilities in terms of specific scientific content. The theoretical basis for this approach along with the specific factors under investigation has been presented in Chapter II.

Tests were constracted to parallel those used by Guilford to define each of the four factors selected from the 'Structure'. Three of the tests thus developed were close in format to those currently being used at the High Aptitudes Research laboratory yet contained reference to the specific science content presented in the experimental treatments. A forth test was developed to measure non-verbal problem solving skills and was originally thought to be in the figural domain. However, subsequent communication with Ralph Hoepfner of U.S.C., indicated that it appeared to be more semantic than figural. After the four tests were submitted to valiadation and reliability procedures, appropiate adjustments were made. The tests (Appendix III) were then administered to 250 students as part of a battery of thirteen test variables and scores resulting from this battery were factor analyzed.

The variables and theoretical factors on which they should load are given. below. The sources from which tests have been obtained is given in parenthesis after the title of the test.

Bkpt --S.U.C., Brockport, Brockport, New York 14420
ETS --Educational Testing Service, Princeton, N.J.
G --Guilford, High Aptitude Psychology laboratory, U. of California, Los Angeles, California

HM --Houghton-Mifflin, 53 W. 43rd. St., New York, New York 10036
SS --Sheridan Supply Co., Box 837, Beverly Hills, California
DAT--The Psychological Corp., 304 E. 45th St., New York, New York 10017

A. Verbal Comprehension Factor
   Variables
   1. Science Vocabulary (Bkpt) Parallel to standard vocabulary test--select the word most similar to the one given. 23 multiple choice items requiring 5 minutes to complete.
   2. Vocabulary (ETS) "A five choice synonym test adopted from the Cooperative Vocabulary Test".

B. Spatial Orientation Factor
   Variables
   3. Science Spatial Orientation (Bkpt) Somewhat parallel to Guilford;s Spatial Orientation--a multiple choice test in which the cause of a change in position of levers (part I) and floating bodies (partII) required identification. This test failed to approximate the form for which it was originally intended and produced some doubt as to its fit in the 'Structure'.
   4. Card Rotation (ETS) "From a group of six drawings of the card rotated or turned over, indicate which are like the Stimulus card (not turned over)." (Guilford, 1960)
   5. Cube Comparison (ETS) "Indicate which items present two drawings that can be of the same cube and which one presents two drawings that cannot be of the same cube." (Guilford, 1960)

C. Sensitivity to Problems (Semantic) Factor
   Variables
   6. ,Seeing Problems (SS) "Subject is asked to list problems that might arise in connection with common objects." (French, 1963)
   7. Seeing Science Deficiences (Bkpt) Parallel to Guilford's. The subject is asked to point out the way in which a described plan or activity is faulty.
   8. Apparatus Test (G) "The subject is asked to suggest two improvements for each common appliance named." (French, 1963)

Test variables for two additional reference factors were included in the test battery to allow the Non-Verbal Problem Solving test to load on already established factors.

D. Closure Factor: Selected because the diagrams used in the Non-Verbal Solving test might play a major role in a student's ability to identify and correct errors.

Variables

9. Hidden Patterns (ETS) "The task is to mark each pattern in which a given configuration appears." (French, 1963)
10. Hidden Figures (ETS) "The task is to decide which of five geometrical figures is embedded in a complex figure." (French, 1963)

E. Numerical Factor: Selected because some of the pictured situations used in the Non-Verbal Problem Solving test included errors of measurement and/or computational errors.

Variables

11. Division (ETS) "Working rapidly, divide 2 or 3-digit numbers by single-digit numbers." (Guilford, 1960)
12. Multiplication and Subtraction (ETS) "Working as rapidly as possible, subtract 2-digit numbers from 2-digit numbers for a set of items, then multiply 2-digit numbers for a second set of items, then repeat subtraction-multiplication sequence for further sets of items." (Guilford, 1960)

The thirteenth test variable was the Non-Verbal Problem solving (Bkpt) constructed for use in this experiment and no reference tests from the already established 'Structure' were available. The test contained errors in arrangement of objects illustrated, measurements recorded on spring balances or computational errors. It was hypothesized that this test could either load on three previously defined factors; numerical ability, closure, and sensitivity to problems or that it might fall in an area of its own.

This battery of thirteen variables was administered to 150 eighth grade students who had completed appropiate science experiences in four randomally selected schools of central western New York State. Results of factor analytic procedures failed to clearly identify two of the science content test variables and it was felt that a second test battery should be analyzed in an attempt to clarify these two test variables.

The second battery was administered in conjunction with those tests being used to evaluate effects of the experimental treatment. New reference tests were added in the second battery in an attempt to find variables similar to those on the Science Spatial Orientation test and the Non-Verbal Problem Solving test. Two reference tests from the initial factor structure were retained in the second battery because of their strength as factor markers.

A. Verbal Comprehension Factor
Variables
1. Science Vocabulary (Bkpt) described above
2. Nelson Silent Reading Test (HM) vocabulary--100 items to measure vocabulary.
3. Nelson Silent Reading Test (HM) Paragraph Comprehension--75 items in blocks of three following a paragraph; one pertaining to general significance of the selection, one to detailed information contained therein, and one planned to assess the ability to predict probable outcomes.

B. Spatial Orientation Factor
Variables
4. Science Spatial Orientation (Bkpt) Described above
5. Hidden Figures (ETS) Described above

C. Evaluation of Semantic Systems
Variables
6. Unusual Details (SS) Point out two incongruities in sketches of common situations. (Guilford, 1960)
7. Mechanical Reasoning (DAT) Student must select one of three alternative answers to a question about a pictured situation. 68 items
8. Non-Verbal Problem Solving (Bkpt) Described above

D. Sensitivity to Problems
Variables
9. Seeing Problems (SS) Described above
10. Seeing Science Deficiencies (Bkpt) Described above.

The second battery of test variables was administered to 145 of the subjects involved in the experimental treatments.

## Sample

Two samples were used in Phase I of this project. Data for the first factor analytic procedure was obtained on 156 subjects in intact eighth grade classes from four randomally selected schools in Western New York State. The battery of thirteen tests was administered in random order in the spring of 1965 after eighth grade students had been exposed to appropiate experiences in science.

Data for the second factor analytic analysis was obtained on 144 of the subjects used in the experimental treatment. (see page 17) The second analysis was recommended because of a lack of clear definition of all test variables administered in the first analysis.

## Statistical Procedures

Factor analysis was accomplished by means of a principle components program in an IBM 7044 at the University of Rochester. The resulting correlation matrix was rotated by means of Cliff's patterened orthogoral rotation by Dr. Ralph Hoepfner at the University of Southern California. The square root of multiple r was used as the communality estimate.

## Phase II

Objectives of phase II of this investigation are concerned with identifying the specific learnings attributable to the independent variable which has been described as method of acquiring supplementary evidence supporting scientific principles developed in a learning sequence. Experimental and statistical hypothesis generated from this objective are stated on page two . Attainment of the experimental objective was achieved by administering experimental conditions to each of twelve randomally selected eighth grade groups in central western New York State. Behaviors arising from exposure to the treatments were measured by four tests developed for this investigation while differences in performance as evidenced by test scores were statistically evaluated by an analysis of covariance.

## Experimental Treatment

Linear Program: A 700 frame linear program, Energy and Work was used as the primary learning experience. (Objectives of the program, classified in terms of Bloom's Taxonomy, are presented in Appendix II.) The program attempted to develop familiarity with scientific principles associated with work and energy. Several content areas were presented and their relationships to work, energy, force, and resistance were clarified. Evidence supporting the principles developed within the program constituted the independent variable.

The linear program was presented in booklet form with correct answers located directly below each frame. A mask was provided with the booklet and subjects were instructed to record their responses before moving the mask down to uncover the correct answer. Constructed responses were required with a ratio confirmation schedule. Confirmation was provided for approximately four out of every five re= sponses. All responses were recorded on a separate answer sheet and subjects were directed to cross out incorrect responses, reread statements to which incorrect responses were made and write the correct response in a blank provided on the answer sheet.

Two major revisions of the program were made based on initial field testing and use in a prior research project. Reading level of the program was maintained at approximately a sixth grade level through editing by Mrs. Floy Delancey, an elementary language arts specialist. Scientific content of the program was verified by two independently working editors from the physics department of SUC at Brockport.

The program was used only during class time and subjects were allowed to progress at their own rate of speed. Subjects completing the program prior to a large majority of the class were requested to bring other reading material or homework to class while classmates finished the program.

Evidence supporting scientific principles presented in the program was gained through:

1) *Active participation* in a series of seventy-three 'cook-book' type experiments,
2) *Reading descriptions* of the seventy-three experiments
or
3) *Observing* a teacher demonstrate the seventy-three experiments.

In each situation the same questions were asked of the subject.

1) *Active participation:* subjects within this group actually participated in completing seventy-three 'cook-book' experiments. Each subject possessed, in addition to the programed text, Energy and Work, a manual containing directions for the experiments and a kit of all necessary materials.
2) *Reading descriptions:* Subjects within this group read descriptions of the seventy-three experiments. Each subject possessed, in addition to the programed text, a manual containing verbal descriptions and diagrams of the seventy-three experiments.

Subjects in both treatment groups one and two were directed to the accompanying manual in the same way. A numbered frame contained in the main program would read, "Turn to activity #1 (-73) for further information." The subject would then refer to the appropiately numbered activity, perform or read depending upon the treatment group, answer the same question and then return to the main program.

3) *Observing:* Subjects within this group were told to ignore statements within the program directing them to, "Turn to activity... such and such." and were told that rather than actually doing or reading about activities their teacher would demonstrate all experiments. Teachers were directed to demonstrate five to eight experiments at the beginning of each class period and then allow subjects the remaining class time to work independently within the same program. Both of the activity booklets and one activity kit was provided for the teacher and teachers were instructed to require subjects to respond to the same questions accompanying activities in both groups one and two. Teachers were further instructed to parallel as closely as possible the information given in the other two treatment groups as evidenced by the activity booklets.

## Sample

Subjects for this experimental were selected from intact, average eighth grade classes in central western New York State. Average was defined negatively as any non-specialized eighth grade class. Approximately thirty schools in the area were contacted and invited to participate in the project. A total of twelve positive responses were secured and a single group from each school was assigned at random to one of the three experimental treatments. Two complete classes were lost during the experimental treatment due to failure of teachers to follow directions.

Sufficient data for statistical analysis was obtained for a N of 245 subjects. These subjects were divided into the three experimental groups as follows:

| | |
|---|---|
| 1) *Active participation* | n=100 |
| 2) *Reading descriptions* | n= 70 |
| 3) *Observing* | n= 75 |

## Data Collected

Group equivalence was achieved through statistical procedures as opposed to experimental manipulations where equivalence is assured through matching. The major requirement of this equating technique is that some score, called the control measure, representing the greatest variance of all groups and yet closely related to criterion tasks, be obtained. Because the learning experience was primarily written verbalization it was obvious that reading ability would be closely associated with both of these requirements. Success on criterion tasks would be partially dependent on reading ability and this ability was further likely to represent the range of prior learning brought to bear within the learning situation.

The Nelson Silent Reading test Form A was administered prior to the experimental treatment control measure. This test contains 175 items: 100 items to measure vocabulary and seventy-five items to measure reading comprehension. Thirty minutes total working time was required for the test.

The four criterion tests used to evaluate learning occuring as a result of experimental treatment have been thoroughly described in Phase I section on pages . Scores from each of the tests were collected for each individual participating in the experiment.

The length of time in terms of class periods for each individual was also recorded. Class periods generally ran around forty-two minutes. This information is presented only as a point of interest and no attempt is made to relate it to criterion scores.

## Statistical Analysis

An analysis of covariance was used to evaluate data collected in this project. This statistical procedure utilizes a control variable for the purpose of adjusting criterion scores to account for inter-group differences. Reading ability was assumed to have the greatest contaminating effect on the dependent variables and would therefore act as the source of most of the inter-group differences. Thus, by using a reading score as the control variable, any portion of the criterion score directly related to reading, as identified through correlations, would be adjusted accordingly.

The Science Vocabulary criterion score was adjusted by the vocabulary score from the Nelson Silent Reading Test. The other three criterion scores: Science Spatial Orientation, Non-Verbal Problem Solving, and Seeing Science Deficiencies were independently analyzed with the total Reading test score as a control. The total reading score is obtained by combining the vocabulary and comprehension scores.

# CHAPTER IV

> "The chief difficulty Alice found at first was in managing her flamingo: she succeeded in getting its body tucked away, comfortably enough, under her arm, with its legs hanging down, but generally, just as she had got its neck nicely straightened out, and was going to give the hedgehog a blow with its head, it would twist itself round and look up in her face, with such a puzzled expression that she could not help bursting out laughing; and, when she had got its head down, and was going to begin again, it was very provoking to find that the hedgehog had unrolled itself, and was in the act of crawling away: besides all this, there was generally a ridge or a furrow in the way wherever she wanted to send the gedgehog to, and, as the doubled-up soldiers were always getting up and walking off to other parts of the ground, Alice soon came to the conclusion that it was a very difficult game indeed."

## RESULTS

### Phase I

Raw scores from the thirteen test variables, described in Chapter III, for 156 eighth grade students were punched on IBM cards and submitted to a principle component analysis on an IBM 7044 at the University of Rochester

The correlation matrix obtained from this analysis (table 2) was forwarded to the University of Southern California where Cliff's patterned orthogonal rotation was performed by Dr. Ralph Hoepfner. The target matrix for rotation was established in accord with the theoretical factor loadings presented in Chapter II. Multiple r's squared were used as communality estimates in the rotations.

The five factors in the solution presented in table 3 are clearly defined by the reference tests. However, only two of the experimental tests constructed for use in this experiment were loaded as hypothesized. The remaining two tests were distributed over two or more factors and their placement within the (SI) becomes ambiguous. A listing of the factors as originally hypothesized and loadings of .30 or over are presented on the following page. Side loadings are presented in parenthesis.

A. Verbal Comprehension Factor (CMU)

| | | | |
|---|---|---|---|
| 11. | Science Vocabulary | .52 | |
| 13. | Apparatus Test | .47 | (.44 CFU) |
| 10. | Vocabulary | .44 | (.34 CFS) |
| 12. | Sci. Spac. Orientation | .36 | (.45 CFS) |

The Science Vocabulary test, with its only significant loading, and the Vocabulary reference test aid in defining this factor. The Science Spatial Orientation loading on this factor may be partially explained by the complex verbal directions required before the test could be successfully approached. The Apparatus Test has been used by Guilford in defining the 'Sensitivity to Problems' factor and more recently to define the factor'Cognition of Sematic Implication'. No explanation is offered at this time for the appearence of this test on the verbal and closure factors.

The Science Vocabulary test is one of the Experimental tests exhibiting a unifactor variance as hypothesized.

B. Spatial Orientation (CFS)

| | | |
|---|---|---|
| 3. | Card Rotation | .56 |
| 4. | Cube Rotation | .52 |

The two tests designed by Guilford to define this factor are only ones with significant loadings. The hypothesized appearence of Science Spatial Orientation failed to materialize, probably because of the complex verbal directions as well as the apparently symbolic content of the test.

C. Closure (CFU)

| | | | |
|---|---|---|---|
| 2. | Hidden Patterns | .64 | |
| 13. | Apparatus | .44 | (.47 CMU) |
| 9. | Non-Verb. Prob. Solv. | .37 | |
| 1. | Hidden Figures | .30 | |

Again, appearence of the apparatus test on this factor is unexplainable. The figural content tests, Hidden Patterns and Hidden Figures have commonly been used to define this factor and continue to adhere to a rather well established pattern. The Non-Verbal Problem Solving test loading on this factor could be accounted for if subjects became too involved with correcting the diagrams used in the test rather than correcting the pictured situations in terms of science content being represented. This explanation is plausible in that diagrams constructed for use in the test used symbols and details

table 1

Means, S.D., and Reliabilities of thirteen test variables

| Test | Name | Means | Standard Deviation | Reliability |
|---|---|---|---|---|
| 1. | Appartus | 12.54 | 5.56 | .63 |
| 2. | Card Rotation | 68.27 | 21.02 | .40* |
| 3. | Cube Comparisons | 9.81 | 2.96 | .41* |
| 4. | Division | 19.23 | 7.28 | .59* |
| 5. | Hidden Figures | 4.42 | 2.69 | .14* |
| 6. | Hidden Patterns | 33.60 | 10.43 | .49* |
| 7. | Multi. and Div. | 25.89 | 8.82 | .52* |
| 8. | Non-Verb. Prob. Solv. | 6.87 | 3.11 | .73 |
| 9. | Sci. Vocab. | 12.49 | 2.92 | .62 |
| 10. | Sci. Spac. Orientation | 11.67 | 3.55 | .84 |
| 11. | Seeing Problems | 12.82 | 11.31 | .52 |
| 12. | Seeing Sci. Deficiencies | 5.56 | 2.46 | .73 |
| 13. | Vocabulary | 15.51 | 5.38 | .35 |

*Obtained communality as lower bound reliability estimate

similar to those in the experimental treatment. S's not familiar with the experimental treatment may very possibly have missed some of the finer content oriented aspects of the diagrams.

D. Sensitivity to Problems (CMI)

| | | | |
|---|---|---|---|
| 5. | Seeing Science Defic. | .55 | |
| 12. | Sci. Spatial Orientation | .45 | (.36 CMU) |
| 8. | Seeing Problems | .44 | |

Nihira and others (1964) have redefined this factor as one of cognition rather than evaluation. The loading of all three tests can be explained more adequately in terms of this more recent placement within the 'SI'. Both the verbal and non-verbal test items gain joint significance when examined in light of a cognitive operation. All items depend on prior experience with the content in question and experience can be brought to bear within the semantic dimension of

## table 2

### thirteen variables

| | Test | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Apparatus | | 06 | 11 | -07 | 15 | 32 | -01 | 16 | 23 | 16 | -34 | 01 | 20 |
| 2. | Card Rotation | 06 | | 44 | 15 | 24 | 30 | 21 | 05 | 06 | 05 | 08 | 08 | 21 |
| 3. | Cube Comparison | 11 | 44 | | 33 | 08 | 23 | 21 | 03 | 20 | 22 | 18 | 26 | 22 |
| 4. | Division | -07 | 15 | 33 | | 08 | -01 | 60 | -05 | 14 | 29 | 34 | 17 | 20 |
| 5. | Hidden Figures | 15 | 24 | 08 | 08 | | 25 | 09 | -01 | -03 | 13 | 11 | 05 | 07 |
| 6. | Hidden Patterns | 32 | 30 | 23 | -01 | 25 | | 05 | -18 | 02 | 04 | -28 | -07 | 00 |
| 7. | Multi. and Div. | -01 | 21 | 21 | 60 | 09 | 05 | | -18 | 02 | 04 | 17 | 06 | 17 |
| 8. | Non-Verb. Prob. Solv. | 11 | 05 | 03 | -05 | -01 | 28 | -18 | | 00 | 11 | 00 | 05 | 11 |
| 9. | Sci. Vocabulary | 23 | 06 | 20 | 14 | -03 | -11 | 02 | 00 | | 30 | 15 | 33 | 34 |
| 10. | Sci. Spac. Orientation | 16 | 05 | 22 | 29 | 13 | -03 | 04 | 11 | 30 | | 19 | 30 | 36 |
| 11. | Seeing Problems | -34 | 08 | 18 | 34 | 11 | -28 | 17 | 00 | 15 | 19 | | 28 | 17 |
| 12. | Seeing Sci. Deficiencies | 01 | 08 | 26 | 17 | 05 | -07 | 07 | 05 | 33 | 30 | 28 | | 34 |
| 13. | Vocabulary | 20 | 20 | 22 | 20 | 07 | 00 | 15 | 11 | 34 | 36 | 17 | 34 | |

*Decimal points have been omitted

### table 3

### Five factor structure

### Rotated Factor Matrix

| | CMU | CFS | EMI | CFU | MSI | $h^2$ |
|---|---|---|---|---|---|---|
| 1. | 47 | 01 | -14 | 44 | -05 | 44 |
| 2. | 04 | 56 | 06 | 24 | 14 | 40 |
| 3. | 18 | 52 | 21 | 15 | 22 | 41 |
| 4. | 06 | 13 | 28 | -02 | 70 | 59 |
| 5. | -04 | 17 | 11 | 30 | 11 | 14 |
| 6. | -01 | 24 | -16 | 63 | -00 | 49 |
| 7. | 02 | 18 | -03 | -02 | 70 | 52 |
| 8. | 02 | -04 | 20 | 37 | -19 | 21 |
| 9. | 52 | 09 | 27 | -09 | 03 | 35 |
| 10. | 36 | -01 | 45 | 11 | 14 | 36 |
| 11. | -13 | 15 | 55 | -28 | 22 | 47 |
| 12. | 30 | 17 | 44 | -09 | 05 | 32 |
| 13. | 44 | 15 | 35 | 08 | 12 | 35 |

Note.---Decimal points omitted.

both Problems and Deficiencies as well as the apparently semantic and symbolic content of the Science Spatial Orientation Test.

The experimental test, Seeing Science Deficiencies, appears to be a relatively factor pure test measuring cognition of semantic implications as originally hypothesized. This 'sensitivity to problems' ability requires both verbal comprehension and verbal responses and is clearly in the semantic domain.

Results of the second factor analysis were not as clear as those from the thirteen variable structure and conflicted somewhat with the earlier pattern. Three of the four experimental tests in this ten variable analysis had significant loadings on a single factor along with one of the new reference tests. A pair of new verbal measures loaded on three of the four factors extracted; hardly the kind of result desired when looking for unifactor measures.

Rotating the matrix toward a target as outlined by Cliff was again used but this time failed to improve the factor structure. The original verimax rotation was then used as the more meaningful structure in terms of hypotheses as well as compatibility with the thirteen factor structure.

Loadings on the four extracted factors in the ten factor analysis are presented below. Significant variable loadings of .30 and

table 4

Means, S.D., and Reliabilities for ten test variables

| Test Name | | Mean | Standard Deviation | Reliability |
|---|---|---|---|---|
| 1. | Hidden Patterns | 50.07 | 15.60 | .35* |
| 2. | Mechanical Reasoning | 44.14 | 7.66 | .44* |
| 3. | Nelson Si. Read., Comp. | 49.63 | 10.14 | .86 |
| 4. | Nelson Si. Read., Vocab. | 66.45 | 8.71 | .85 |
| 5. | Non-Verb. Prob. Solv. | 7.65 | 3.01 | .65 |
| 6. | Sci. Spac. Orientation | 9.02 | 3.25 | .84 |
| 7. | Sci. Vocabulary | 13.15 | 2.55 | .62 |
| 8. | Seeing Problems | 18.72 | 6.57 | .21* |
| 9. | Seeing Sci. Defic. | 5.55 | 2.30 | .73 |
| 10. | Unusual Details | 5.97 | 2.25 | .54* |

*Obtained communality as lower bound reliability estimate

above are reported under appropiate factor headings.

Verbal Comprehension Factor (CMU)

| | | | |
|---|---|---|---|
| Science Vocabulary | .49 | (.33 Sci) | |
| Nelson Si. Read., Comp. | .44 | (.58 Com) | (.50 Ach) |
| Seeing Problems | .39 | | |
| Nelson Si. Read., Vocab. | .38 | (.56 Comp) | (.51 Ach) |

Four of the six tests requiring some form of verbal ability loaded on this factor. All of these variables are in the semantic cognitive domain, and although the product aspect of the tests were different, there was apparently not enough difference to pull the tests off this verbal factor. The units aspect of the factor as evidenced by the two vocabulary tests is one of the stronger features of the factor.

Because of the significant side loadings this factor appears to be fairly weak.

Science Content Factor (Sci)

| | |
|---|---|
| Non-Verbal Prob. Solv. | .65 |
| Mechanical Reasoning | .64 |

table 5

ten variables

Correlation Matrix*

|  | Table | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Hidden Patterns |  | 26 | 38 | 40 | 20 | 17 | 24 | 15 | 23 | 40 |
| 2. | Mechanical Reasoning | 26 |  | 06 | 13 | 44 | 25 | 20 | -04 | 30 | 07 |
| 3. | Nelson Si. Read., Comp. | 38 | 06 |  | 76 | 16 | 06 | 36 | 32 | 40 | 50 |
| 4. | Nelson Si. Read., Vocab. | 40 | 13 | 76 |  | 15 | 09 | 37 | 28 | 40 | 49 |
| 5. | Non-Verb. Prob. Solv. | 20 | 44 | 16 | 15 |  | 30 | 29 | 02 | 30 | 20 |
| 6. | Sci. Spac. Orientation | 17 | 25 | 06 | 10 | 30 |  | 20 | -01 | 20 | -04 |
| 7. | Sci. Vocabulary | 24 | 21 | 36 | 37 | 29 | 20 |  | 24 | 18 | 24 |
| 8. | Seeing Problems | 15 | -04 | 32 | 28 | 02 | -01 | 24 |  | 20 | 23 |
| 9. | Seeing Sci. Defic. | 22 | 30 | 40 | 40 | 30 | 20 | 18 | 19 |  | 12 |
| 10. | Unusual Details | 4] | 07 | 50 | 49 | 20 | -04 | 24 | 23 | 12 |  |

*Decimal points have been omitted

table 6

Four Factor Structure

Rotated Factor Matrix
ten variables

| | Comp. | Sci. | Ach. | CMU | $h^2$ |
|---|---|---|---|---|---|
| 1. | 17 | 26 | 49 | 11 | 35 |
| 2. | 08 | 64 | 13 | -08 | 44 |
| 3. | 58 | 01 | 50 | 44 | 78 |
| 4. | 56 | 07 | 51 | 38 | 72 |
| 5. | 03 | 65 | 16 | 10 | 45 |
| 6. | 09 | 45 | -05 | 07 | 22 |
| 7. | 07 | 32 | 20 | 49 | 38 |
| 8. | 17 | 05 | 15 | 39 | 21 |
| 9. | 51 | 37 | 07 | 12 | 42 |
| 10. | 08 | 02 | 69 | 23 | 54 |

Science Content Factor (Sci.) Continued

| | | |
|---|---|---|
| Science. Spa. Orien. | .45 | |
| Seeing Sci. Defic. | .37 | (.51 Comp) |
| Science Vocab. | .32 | (.49 CMU) |

Although all tests with science oriented content loaded on this factor it is obvious that the three non-verbal tests represent the strongest variables. Both of the verbal tests listed here have higher side loadings on other factors.

The Non-Verbal Problem Solving and Mechanical Reasoning tests are extremely similar as one might suspect from the loadings. Both tests contain situations depicting science oriented content with the primary difference lying in the response form. The Non-Verbal Problem Solving test requires a correction in the pictured situation while the Mechanical Reasoning test requires a choice about the illustrated situation.

The Science Spatial Orientation test requires knowledge of levers and floating bodies but unfortunately the complicated directions and symbols used in the test completely confused its original intent. The test has a high 'symbolic' content and apparently correct answers could be selected either because of this or because of its semantic content.

This factor could well be defined by the first two Non-Verbal test variables as evidenced by their highly significant loadings. The

Non-Verbal Problem Solving and Mechanical Reasoning tests are very similar to Seeing Science Deficiencies in product and operation involved. The Semantic content of the three tests, verbal in one instance and non-verbal in the other two, appears to be major difference between this and the (Comp) factor of this structure and the CMI factor in the thirteen variable structure. Although not a clearly defined independent ability in the general intellectual domain, it may very well emerge in content oriented test situations. This aspect of the investigation clearly requires further study and could aid in clarifying non-verbal abilities resulting from content oriented instruction.

Comprehension Factor (Comp)

| | | | |
|---|---|---|---|
| Nelson Si. Read., Comp., (Part II) | (.58) | (.50 Ach) | (.44V) |
| Nelson Si. Read., Vocab. (Part 1 ) | (.56) | (.51 Ach) | (.48V) |
| Seeing Science Deficiencies | (.51) | (.37 Sci.) | |

Comprehension is apparently the common denominator of the three tests defining this factor and appears to be a combination of Guilford's Cognition of Semantic Relations and Cognition of Semantic Units. Both the Part II portion of the standardized reading test and entire Seeing Science Deficiencies test require the subject to read a short selection and then react to a question or questions about the selection. Tasks on these tests would appear to require ability to identify relationships of the semantic content presented. Vocabulary tests have traditionally been classified within the units dimension and no evidence to the contrary is available here.

The difference between this (Comp) factor and the (Sci) factor has not been clarified in any previous work. There appears to be some distinction between 'verbal' and 'non-verbal' cognitions but that distinction has not been empirically demonstrated in the non-content oriented reference tests used in most factor analytic studies.

Achievement Factor (Ach)

| | | | |
|---|---|---|---|
| Unusual Details | .69 | | |
| Nelson Silent Read., Vocab. | .51 | (.56 Comp) | (.38V) |
| Nelson Silent Read., Comp. | .50 | (.58 Comp) | (.44V) |
| Hidden Patterns | .49 | | |

The loadings exhibited by the Reading tests appear to be indicative of a general achievement ability showing up whenever verbalization is required.

The Unusual Details test required a written response to a pictured situation. Although the recorded response was corrected for its indication of discrepencies in the pictured situations and not for its clarity or communicative nature, the responses apparently required semantic cognitive ability somewhat similar to those shown in the Reading tests.

The Hidden Patterns test has frequently shown up strongly on a factor called closure and was used here only for the purpose of indicating that the diagrams being used in experimental tests were not complicated by this factor. It is entirely possible that if allowed to do so, this test would move off to define a factor of its own, for it is the only test that has exhibited strong unifactor traits in previous studies. It is entirely possible that the other three tests are too multifactor oriented to have any meaning in this type of statistical treatment.

## Phase II

Effects of the three experimental treatments were measured by four paper and pencil tests. Raw scores from each test were independently treated and were evaluated statistically by means of a covariance analysis. The control variable for each test analysis consisted of the vocabulary score alone or vocabulary score and reading comprehension score from the Nelson Silent Reading Test. It may be recalled that a control variable in the covariance analysis is used to statistically equate groups and should therefore measure those factors responsible for differences on criterion measures that are not attributable to the experimental variable. Adjustment of criterion scores is based on the degree of score variance that can be attributed to performance on the control variables. It was assumed that reading would contribute the greatest contaminating variance and elimination of differences due to reading ability would provide the most accurate measurement for the purpose of equating the three experimental groups.

Each of the four tests are treated independently in the following tables to comply with the four experimental hypothesis. Each table presents both adjusted scores and S.D.'s for the dependent variable as well as means and S.D.'s of the control variable or variables.

*$H_1$ There is no statistically significant difference between participation is science activities on a non-verbal measure designed to evaluate sensitivity to problems than reading about or observing those activities.*

Non-Verbal Sensitivity to problems is apparently increased

## table 7

### Non-Verbal Problem Solving Test ($H_1$)
### Analysis of Covariance

| | | Control Variable | | | | Dependent Variable | | |
|---|---|---|---|---|---|---|---|---|
| | | Vocabulary | | Comprehension | | Unadjusted | | Adjusted |
| Group | N | M | S.D. | M | S.D. | M | S.D. | M |
| I (Part) | 100 | 70.24 | 8.39 | 53.20 | 11.07 | 8.32 | 3.38 | 8.20 |
| II (Read) | 70 | 64.47 | 6.99 | 48.64 | 8.48 | 6.39 | 2.97 | 6.38 |
| III (Dem) | 75 | 62.12 | 7.21 | 46.31 | 9.06 | 6.35 | 3.07 | 6.51 |
| | | | | | | | | Adj F=5.88* |

*Significant at .01 level

## table 8

### Seeing Science Deficiences Test ($H_2$)
### Analysis of Covariance

| | | Control Variable | | | | Dependent Variable | | |
|---|---|---|---|---|---|---|---|---|
| | | Vocabulary | | Comprehension | | Unadjusted | | Adjusted |
| Group | N | M | S.D. | M | S.D. | M | S.D. | M |
| I (Part) | 100 | 70.24 | 8.39 | 53.20 | 11.07 | 5.77 | 2,51 | 5.46 |
| II (Read) | 70 | 64.47 | 6.99 | 48.64 | 8.48 | 4.83 | 2.55 | 4.95 |
| III (Dem) | 75 | 62.12 | 7.21 | 46.31 | 9.06 | 5.39 | 2.40 | 5.69 |
| | | | | | | | Adj. | F=1.80 N.S. |

most significantly by active manipulation of data as evidenced by the significant F-ratio obtained in the statistical evaluation of scores resulting from the criterion instrument used to test this hypothesis. Results of this test, along with both control scores, are presented in table 7. It is apparent from visual inspection of adjusted group means on the criterion variable that group one obtained the one score that was significantly different from group two and group three.

### table 9

### Science Vocabulary ($H_3$)
### Analysis of Covariance

| | | Control Variable Vocabulary | | Dependent Variable Unadjusted | | Adjusted |
|---|---|---|---|---|---|---|
| Group | N | M | S.D. | M | S.D. | M |
| I (Part) | 100 | 70.24 | 8.39 | 13.87 | 2.64 | 13.34 |
| II (Read) | 70 | 64.47 | 6.99 | 12.54 | 2.39 | 12.75 |
| III (Dem) | 75 | 62.12 | 7.21 | 12.84 | 2.95 | 13.34 |

Adj. F=1.40 N.S.

### table 10

### Science Spatial Orientation ($H_4$)
### Analysis of Covariance

| | | Control Variable Vocabulary | | Comprehension | | Dependent Variable Unadjusted | | Adjusted |
|---|---|---|---|---|---|---|---|---|
| Group | N | M | S.D. | M | S.D. | M | S.D. | M |
| I (Part) | 100 | 70.24 | 8.39 | 53.20 | 11.07 | 8.47 | 3.32 | 8.24 |
| II (Read) | 70 | 64.47 | 6.99 | 48.64 | 8.48 | 8.40 | 3.00 | 8.49 |
| III (Dem) | 75 | 62.12 | 7.21 | 46.31 | 9.06 | 9.23 | 3.21 | 9.44 |

Adj. F=2.80 N.S.

*$H_2$ There is no statistically significant difference between participation in science activities on a verbal measure designed to evaluate sensitivity to problems than reading about or observing those activities.*

The F ratio obtained from the statistical evaluation presented in table 8 is non-significant and a 'fail to reject' of $H_2$ is indicated. Thus, a verbal 'sensitivity to problems' evaluation instrument fails to differentiate effects of the three experimental treatments.

*$H_3$ There is no statistically significant difference between participation in science activities on a verbal test measure designed to evaluate vocabulary than reading about or observing those activities.*

Table 9 presents the results of the science vocabulary test. The vocabulary score from the Nelson Silent Reading test was used alone as the control variable for the statistical analysis of scores obtained from this test. It may be observed that the statistically non-significant F-ratio may be accepted as a 'failure to reject' the null hypothesis.

*$H_4$ There is no statistically significant difference between participation in science activities on a non-verbal measure designed to evaluate ability to orient oneself to changes in three dimensional space than reading about or observing those activities.*

Results of performance on the Spatial Orientation test are presented in table 10. Both vocabulary and reading comprehension scores were used as control variables in this evaluation. Although the F-ratio is statistically non-significant it may be observed that the dependent score mean for group three is somewhat higher than means for either group one or group two. It may be recalled from Phase I results that this test failed to measure the unifactor ability that was originally hypothesized and that results of the test became somewhat confused.

Table 11 presents the average number of periods taken to complete each experimental treatment.

table 11

Number of Class Periods Taken to Complete Each Experimental Treatment*

|  | N | Average number of Class Periods |
|---|---|---|
| Group One | 100 | 11.0 |
| Group Two | 70 | 9.7 |
| Group Three | 75 | 10.3 |

* Class periods average forty-two minutes.

# CHAPTER V

"I know what you're thinking about," said Tweedledum; "but it ain't so, nohow."
"Contrariwise," continued Tweedledee, "if it might be; and if it were so, it would be; but as it ain't, it ain't. That's logic."

## CONCLUSIONS

Three content oriented independent abilities were identified in Phase I of the study. Two of the idenpendent abilities, Cognition of Semantic Units and Cognition of Semantic Implications are similar to those abilities identified and defined in the 'Structure of Intellect' (SI). A third ability, although within the same cognition implication dimensions, appears to have been drawn away from a corresponding cell of the SI as a result of its academic content. Three factor pure tests designed to measure these abilities were also developed as a part of the Phase I investigation.

The unifactor tests were then used to evaluate effects of three methods of accompanying programed materials with information supporting scientific principles developed within the program. One of the independent abilities identified in Phase I was effective in differentiating among the three independent variables used in the experimental treatment.

Active participation in obtaining evidence supporting scientific principles presented in a linear program was significantly superior in developing an ability to identify and correct discrepancies in pictured situations. The remaining two methods of acquiring supporting evidence; reading about the experiments or observing a teacher demonstrate the activities, were roughly equal to each other.

The three experimental methods were not statistically different in developing knowledge of vocabulary or ability to detect discrepancies within verbally presented material. Methods of acquiring evidence supporting scientific principles apparently has no effect on the distinctly verbal abilities involved in discriminations within semantic relationships or vocabulary.

Finally, the use of 'factor-pure' tests to detect differences in relatively brief learning episodes has been successfully demonstrated. Although any educational experience is apt to produce some change in behavior, the specific behavior promoted by specific experience can be more precisely identified by the foregoing procedures.

## Discussion

The attempt to identify and define science content oriented factors of ability parallel to those in the theoretical framework, (SI) met with satisfactory success. Of the four experimental tests developed for use in the investigation, three have demonstrated tendencies required for measurement of unifactor traits first outlined by Guilford.

From the first factor analysis (thirteen variables), Seeing Science Deficiencies loaded on a factor along with reference tests used to define the ability: 'cognition of semantic implications'. The implications arising from semantic content requiring prior experience is apparently an independent ability that may be demonstrated in a content area as well as within the general intellectual domain. More precisely, this ability as it has been used in this study, is the identification of discrepancies within a paragraph where situations described involve violations of scientific principles. This'sensitivity to problems' at the verbal or semantic level is one of the independent abilities originally hypothesized for this age level.

Also exhibiting unifactor traits fitting into the (SI)format is the Science Vocabulary test. Cognition of Semantic Units, as this ability is defined, apparently does not depend on the content nature of the units. In this particular study the units were words associated with the scientific principles developed in the program.

It thus appears that two distinctly content oriented tests, constructed similar to those from the (SI) model, maintain variances on the factors of the parallel non-content tests. Thus, content can be successfully introduced into factor pure tests and still maintain unifactor traits.

The Non-Verbal Problem Solving test creates some problems in that it does not fall into a previously defined cell within the (SI). Figural tests of a similar nature have previously collapsed on semantic factors. The very similar Mechanical Reasoning test has been used in studies associated with the (SI) model but has failed to emerge as a unifactor variable. It appears that the content nature of these tests provides them with semantic rather than figural content. If this is true then these non-verbal tests should measure cognition of semantic implications like their verbal counterparts and should have variances from semantic cognitive factors. However, this was not clearly the case in either of the factor analytic sturctures obtained in this study. The strong loading of these two variables, in the second factor analysis, on a single factor, provides some evidence of a unifactor trait. However, the exact nature of the variance remains somewhat obscure.

The Science Spatial Orientation test originally intended to parallel test variables traditionally loading on the Cognition of Figural Systems factor, failed to exhibit any of the unifactor traits desired in this investigation. The academic content oriented approach prevented adherence to the figural content category and complicated directions contaminated the test with semantic content. The test is apparently a multi-factor variable with both semantic and symbolic content requiring cognitive processes. As such, it has little value in differentiating approaches to learning scientific principles outlined as the primary objective of this study.

The use of the 'factor pure' tests in evaluating differential effects of an educational experience also proved successful. It was originally hypothesized that if Guilford's (SI) was accurate then independent abilities should be effected by specific stimuli within learning episodes. It was further predicted that tests of independent abilities could be used to differentiate between two classes of stimuli more readily than broad criterion measures normally used in educational research.

Unifactor measures developed in Phase I of this study were used as dependent variables in Phase II of the study in an attempt to evaluate the effects of active involvement in acquiring knowledge about scientific principles. Of the three unifactor measures developed in Phase I, one differentiated among effects of the experimental treatments. The Non-Verbal Problem Solving test, measuring an ability defined within the (SI) dimensions of cognitive implication, presented evidence that one experimental group performed more effeciently than the other two experimental groups. A conclusion was therefore drawn to the effect that one experimental treatment develops one independent junior high student ability in a specific content area more effeciently than other experimental treatments. Higher scores by the participation group on the 'sensitivity to problems' test supports the use of laboratory sessions with junior high students. Actual work with referent material apparently increases ability to recognize and correct discrepancies in pictured situations. The specific discrepancies detected in this instance involved violations of scientific principles and would therefore seem to indicate a broader understanding of the scientific principles learned than that developed by reading about or observing the activities. Further supporting the broader understanding conclusion is the fact that the participation group performed just as successfully on both of the verbally oriented tests as did the two remaining experimental groups.

The two remaining tests failed to distinguish among effects of the experimental treatments and evidence supported the conclusion that treatment has no effect upon the independent abilities of Cognition of Semantic Units and Cognition of Semantic Implication. Vocabulary and Seeing Science Deficiencies were the test variables measuring these independent abilities and they were not differentially effected by the three experimental treatments used in this investigation.

Not only do the results of this investigation provide a definite purpose for including laboratory sessions at the junior high level but they provide directions for the construction of paper and pencil measurement instruments in evaluating educational experiences. Because broad criterion instruments are generally multi-factor measures they are less sensitive to independent abilities than instruments empirically demonstrated as unifactor measures. Thus, rather than establishing that one educational experience is superior to another, independent ability measurement may lead to more exacting knowledge about how one educational experience is better than another. It may also allow us to find how each educational experience contributes to the total intellectual development of subjects.

## Summary

Earlier studies by this investigator and evidence from aptitudes research have led to the development of hypotheses contending that junior high students possess independent abilities that can be identified, defined and measured. It was further hypothesized that appropiate content oriented instruments designed to measure such unifactor traits would be more successful in detecting differences resulting from variables in educational experiences than commonly used achievement tests.

Two test batteries, one of thirteen variables and one of ten variables, were factor analyzed to identify relationships of newly developed experimental tests with reference tests already demonstrating unifactor traits. Of the four content tests developed, three demonstrated characteristics of tests designed to measure independent abilities. Two of the tests are clearly within the 'Structure of Intellect' (SI) framework. The third factor-pure test did not appear to fit into the non-content oriented sturcture developed by Guilford and associates.

**The factor-pure tests were then used to evaluate three variations of an educational experience. A 700 frame linear program designed to promote understanding of physical science principles was administered to 245 eighth grade students in intact, randomally selected classes. 100 students (Part.) performed seventy-three science experiments while progressing through the program. Seventy-five students (Read.) read descriptions of the experiments while progressing through the program and seventy students (Dem.) observed a teacher demonstrate the experiments during their progress through the program. Approximately ten class periods were required to complete the entire program and accompanying activites.**

**An analysis of covariance was used to statistically evaluate scores from the three factor-pure tests with standardized reading test scores being used as the control variables. The (Part.) group scored significantly higher than either of the other groups on the non-verbal sensitivity to problems test. There were no significant differences in performance of the three groups on the vocabulary test or verbal sensitivity to problems measure.**

**It was concluded that active participation in experiments supporting scientific principles was superior for development of at least one phase of non-verbal problem solving ability. No such superiority of method was evident when verbal abilities were being measured.**

**In general the research project has further demonstrated the feasibility of developing unifactor test instruments for the purpose of detecting precisely how limited variables in educational experiences effect student behavior.**

# APPENDIX I

## Sample of Linear Program
## and Accompanying Activities
## for (Part.) and (Read.) Groups

48. Force required to move an object across a surface is obtained by attaching a spring balance to the object, then pulling the spring balance and noting the weight reading on the balance. A ruler may be used to measure ____________ through which the object is moved.

48. distance

49. To find the amount of work accomplished when an object is moved across a surface we must find the a) ________ required to overcome the resistance of friction and b) ____________ through which the object is moved.

49. a.) force b.) distance

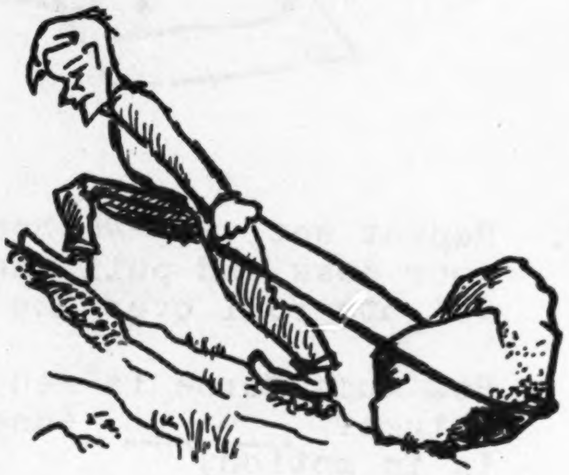
50 To obtain a measure of the work accomplished, we will multiply force times distance and will use the label ____________

50. ft. lbs. or in. ozs.

51. Turn to activity #6 for further information.

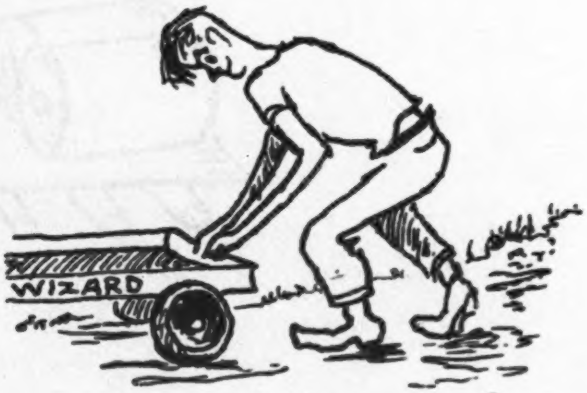
52. Turn to activity #7 for further information.

53. When an object is rolled over a surface, mush less ________ is required than when the object slides over the surface.



53. force

54. More force is required to move an object across a surface when the object is in direct contact with the surface than when rollers are between the object and the surface. Less ________ is needed when the resistance of friction is reduced.

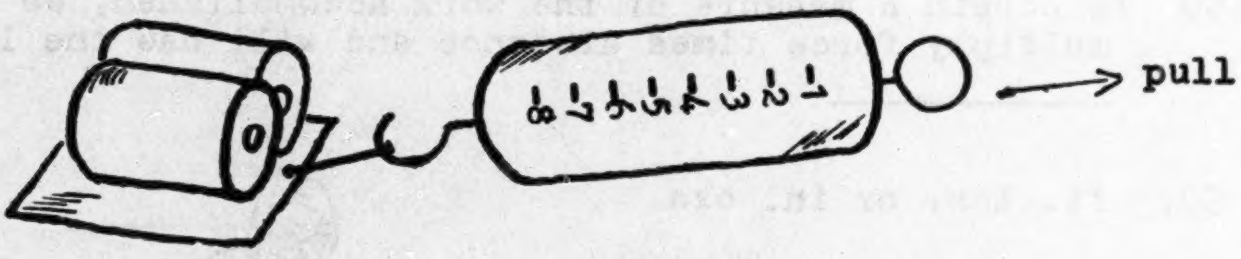


### Activities
### for (Part.) Group

6. Place the two dry cells on a square piece of cardboard. Attach the hook on the spring balance to a piece of string tied to the cardboard. Pull the cardboard across your desk by pulling the ring on the spring balance slowly and steadily.

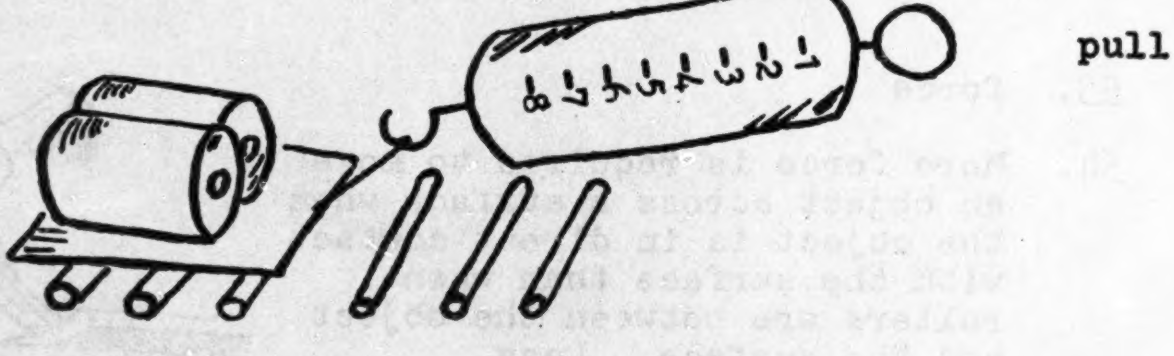
   a. What is the reading on the scales? _____ (use the average reading while the cardboard is in motion)

   b. How much force is required to pull the weights and the cardboard across your desk? ____



7. Repeat activity #6 but this time place some soda straws on your desk and pull the spring balance so the cardboard and weights roll over the straws.

   How much force is required to pull the cardboard and weight? _______ (use average force while the cardboard is in motion)

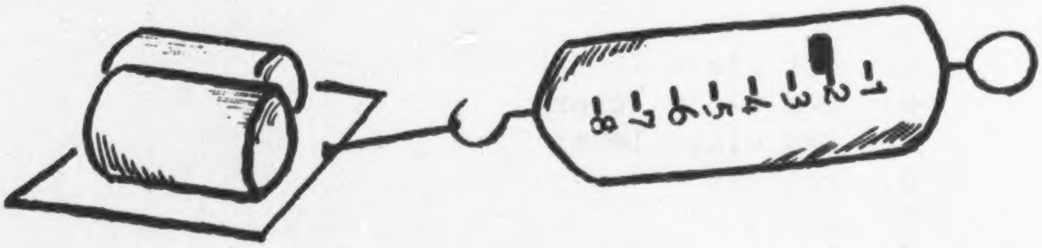


## Activities
## for (Read.) Group

6. If two weights are placed on a piece of cardboard and a spring balance used to pull the bardboard across a table, we have the situation shown in the diagram.

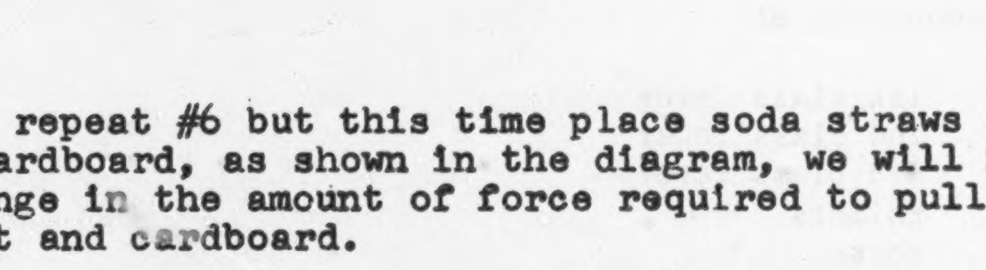
   a. What is the reading on the scales? __________

   b. How much force is required to pull the weights and cardboard across your desk? __________



7. If we repeat #6 but this time place soda straws under the cardboard, as shown in the diagram, we will notice a change in the amount of force required to pull the weight and cardboard.

   How much force is required to pull the weight and cardboard across the soda straws? __________



# Appendix II

## Objectives of the Linear Program

I. Knowledge of Specific Facts

A. General

1. the recall of facts about the operation of devices
2. the recall of facts about the components of devices
3. the recall of facts about the construction of devices
4. the recall of facts about the measurement of specific quantities

B. Specific

The above general objectives will be applied to the following situations

1. operations of:
    - a. 1st class lever
    - b. 2nd class lever
    - c. 3rd class lever
    - d. rollers
    - e. gears
    - f. inclined plane
2. components of:
    - a. 1st class lever
    - b. 2nd class lever
    - c. 3rd class lever
    - d. rollers
    - e. gears
    - f. inclined plane
    - g. complete circuit
    - h. electromagnet
    - i. permanent magnet
    - j. dry cell
3. construction of:
    - a. simple machines (see a-i above)
    - b. complete circuit
    - c. electromagnet
    - d. permanent magnet
    - e. series circuit with dry cells
    - f. parallel circuit with dry cells
4. reduction of friction

5. measurement of:

   a. force
   b. work
   c. energy
   d. displacement
   e. mechanical advantage
   f. use of left hand rule

## II. Knowledge of Terminology

### A. General

1. mastery of terms peculiar to work with--work, force, and energy

2. define technical terms by giving their attributes, function and properties

### B Specific

The above general objectives will be applied to the following terms.

Archimedes' Principle
complete circuit
conductor
conservation of energy
displacement
electromagnet
electromagnetic field
electromotive force
energy
force
friction
gravity
insulator
kinetic
magnet
magnetic field
magnetic poles
mechanical advantage
mechanical efficiency
non-conductor
pitch
potential
radiant
radiation
simple machine
vibration
water pressure
work

## III. Knowledge of Principles and Generalizations

### A. General

1. the recall of generalizations with respect to the operation of devices

2. the recall of generalizations with respect to the measurement of quantities

3. the recall of principles underlying the operation, construction, identification and measurement with respect to specific situations

### B. Specific

1. operation of:

   a. simple machines

- b. magnet
- c. electromagnet
- d. complete circuit
- e. parallet circuit
- f. series circuit

2. measurement of;

   - a. force
   - b. work
   - c. energy
   - d. displacement
   - e. mechanical advantage

3. principles

   - a. Archimedes' Principle
   - b. left hand rule
   - c. Law of conservation of energy
   - d. force required
   - e. energy used
   - f. work accomplished
   - g. mechanical advantage
   - h. electromagnet
   - i. permanent magnet
   - j. simple machines
   - k. complete circuit
   - l. series circuit
   - m. parallel circuit
   - n. pitch
   - o. transfer of energy
   - p. mechanical efficiency
   - q. sound production
   - r. friction

## IV. Application

A. General

The ability to apply scientific principles to new situations

B. Specific

The following principles will be applied to situations not previously encountered by students

1. Archimedes' Principle
2. left hand rule
3. Law of conservation of energy
4. measurement of work, force and energy
5. measurement of mechanical advantage and efficiency
6. transfer of energy
7. complete circuit
8. series circuit
9. parallel circuit
10. forms of energy

11. magnetic field
12. electromagnetic field
13. sound
14. gravity
15. simple machines

# APPENDIX III

## Experimental Tests used to Evaluate Experimental Variables

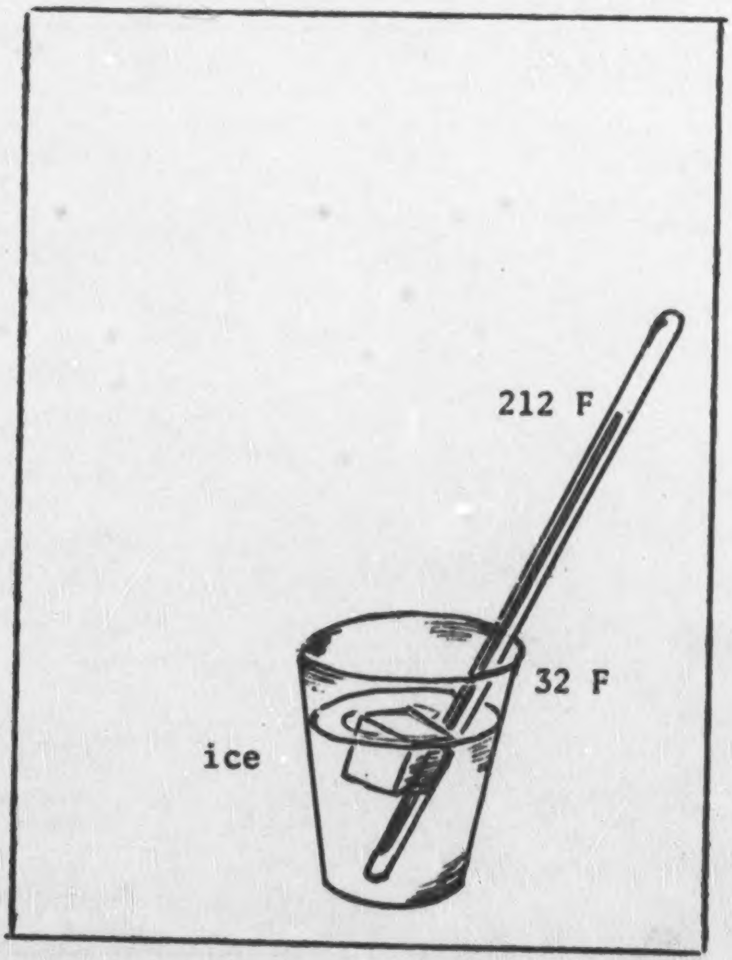
### Seeing Science Deficiencies

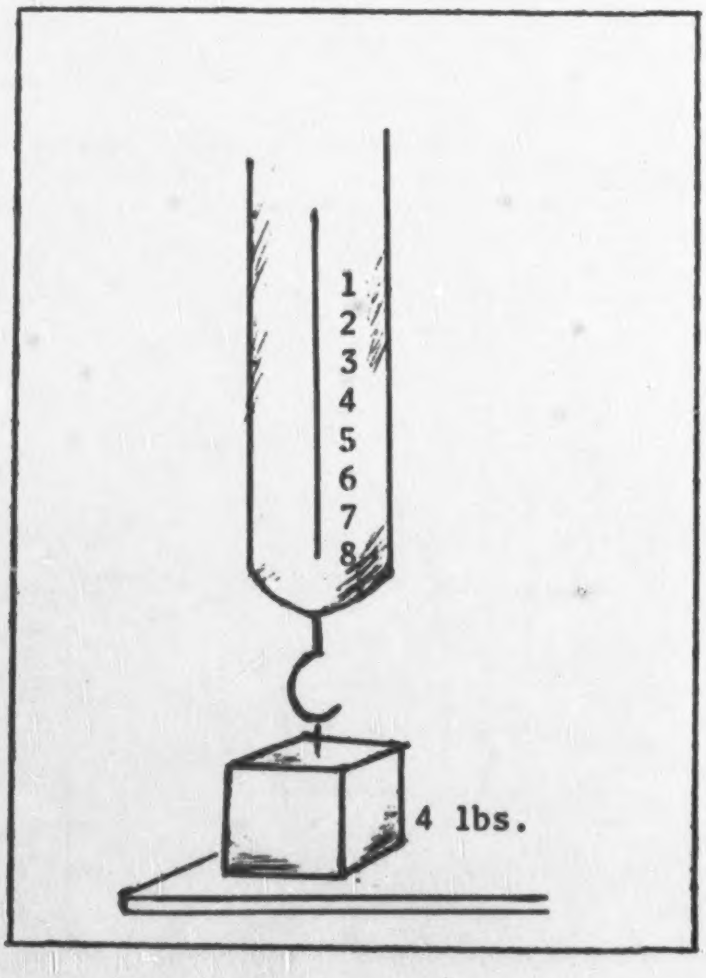
Directions

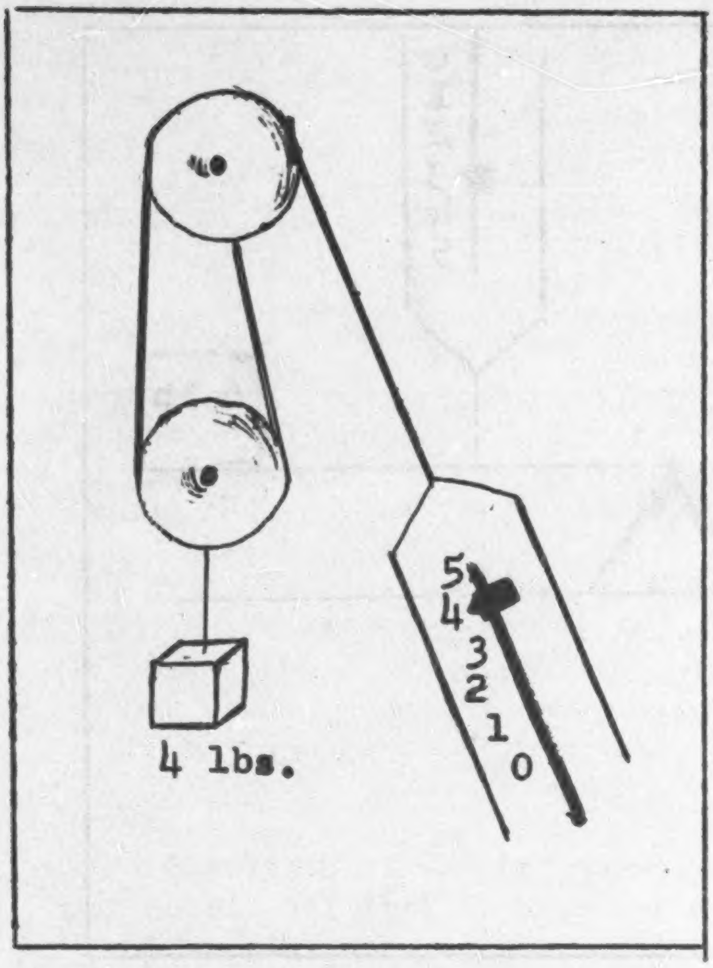
This is a test of your ability to find and correct errors in pictured situations. The diagrams in this test have at least one thing wrong with them. You are to cross out that part of the diagram that is incorrect and/or add something that will correct the situation illustrated. In some cases this may mean corssing out a number or a measurement and replacing it with one that is more realistic. It may mean crossing out or changing an arrow that is indicating direction or it may merely mean that something must be added to the diagram. It may be possible to suggest several corrections for some of the errors pictured. Select the one correction that seems most appropiate and simplets.

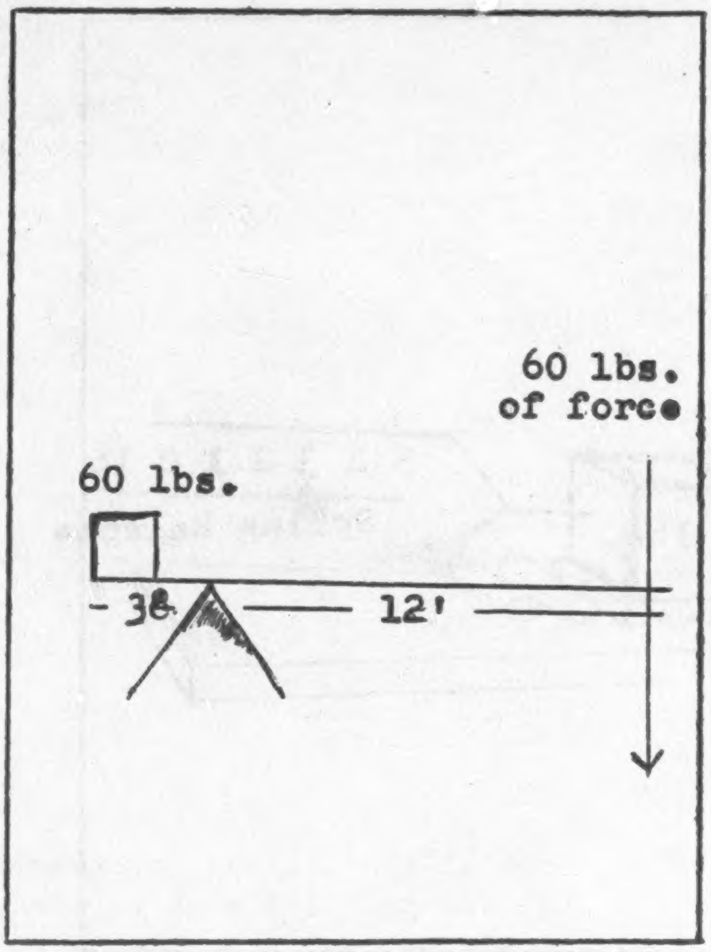
Look at the diagram in Example A. Can you find what is wrong in the picture? How would you change the diagram to correct the error? How can the diagram be changed?

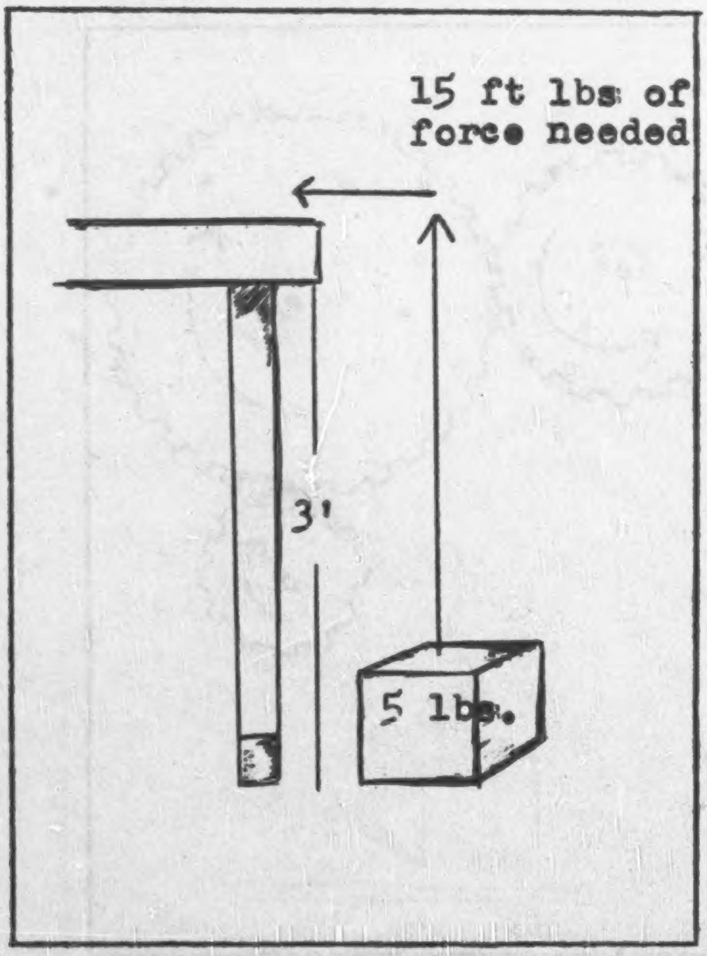
The spring balance in diagram B is being used to lift the block of wood. What is wrong with the situation shown? How can it be corrected?

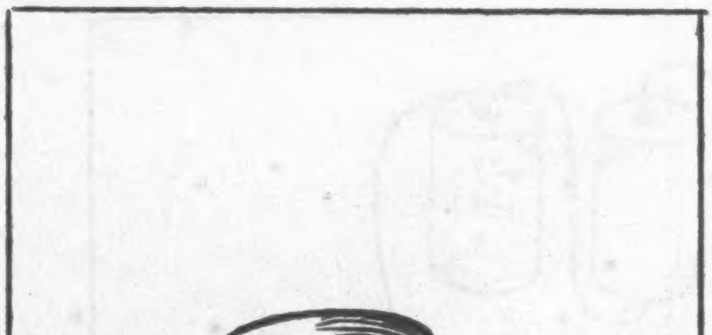


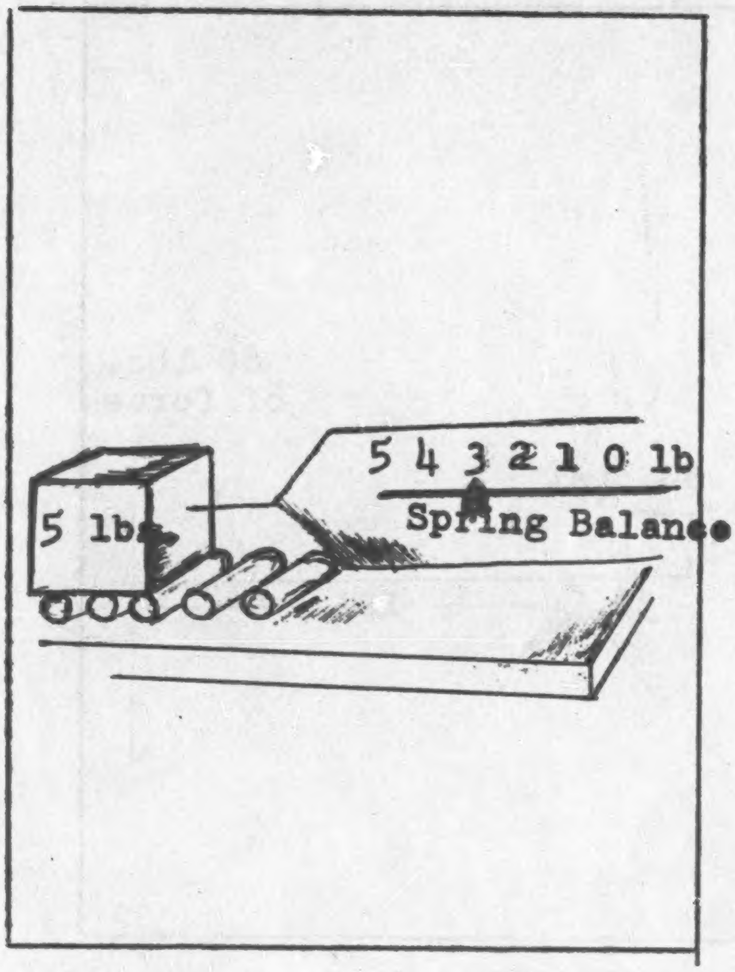


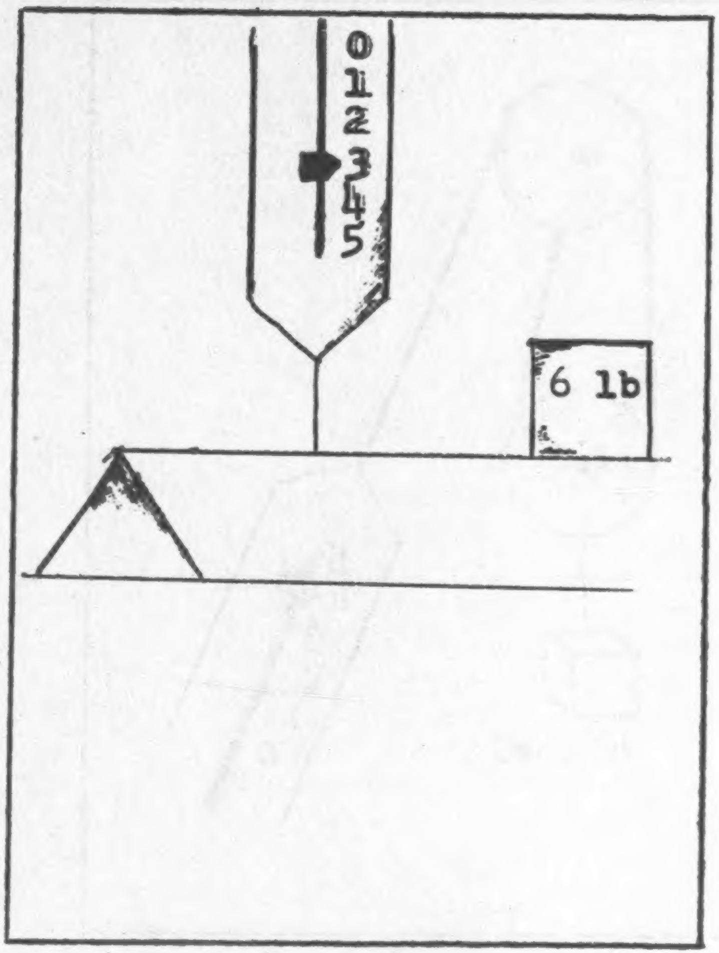

5
4
3
2
1
0
4 lbs.

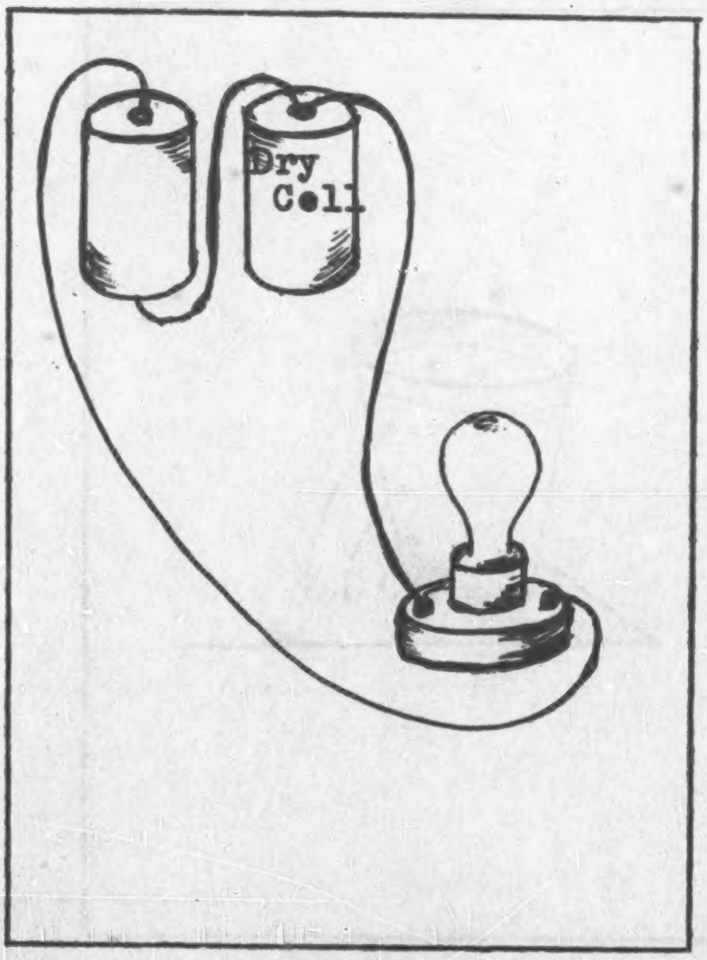

60 lbs.
of force
60 lbs.
3'
12'

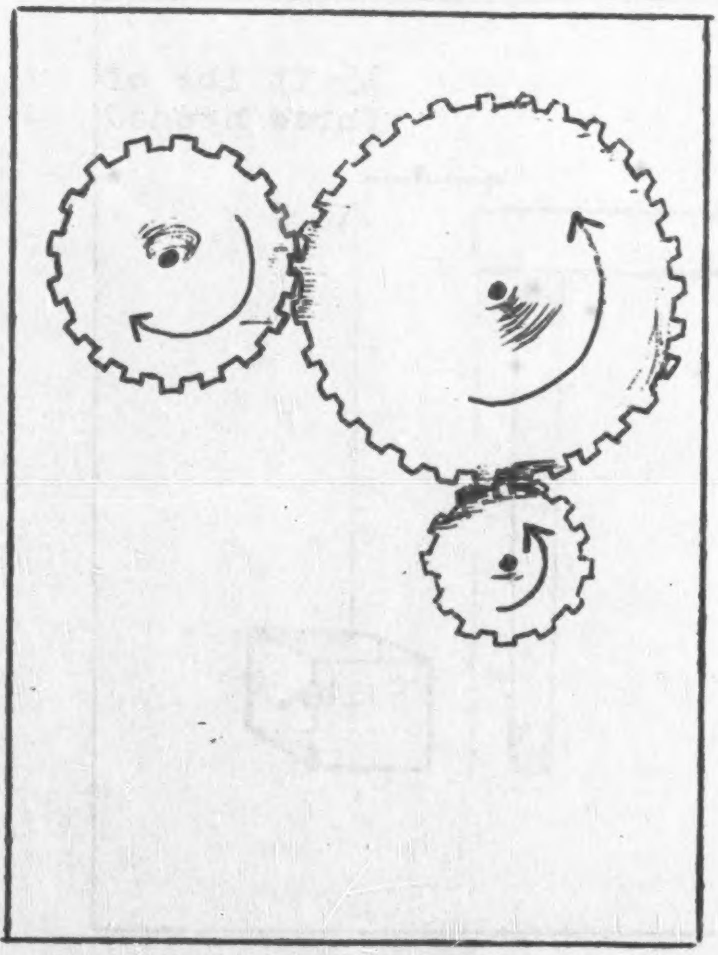

15 ft lbs of
force needed
3'
5 lbs.

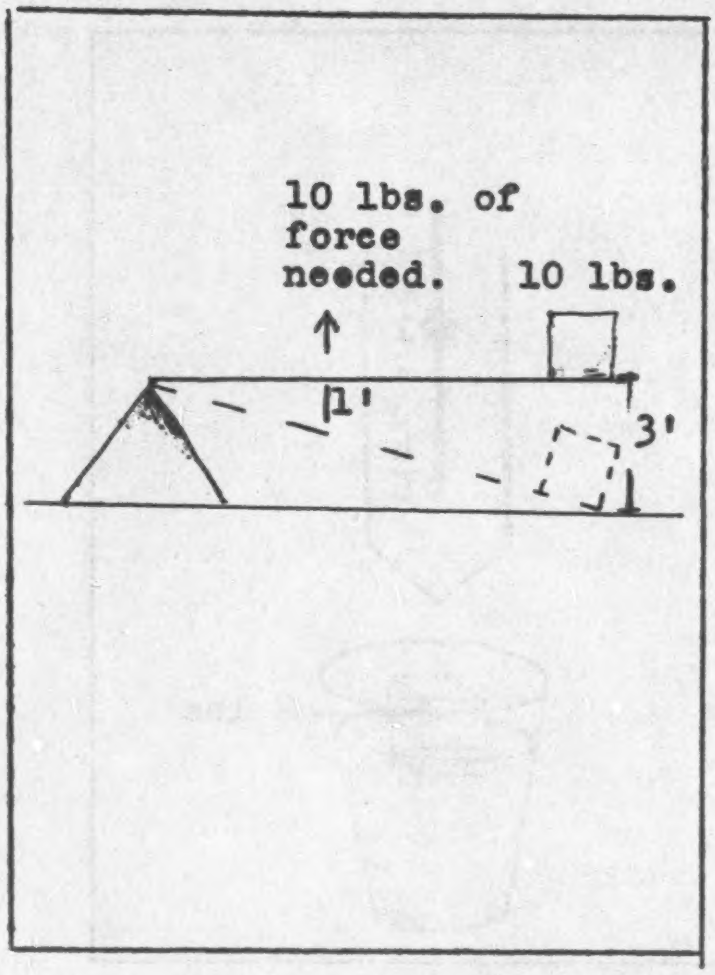


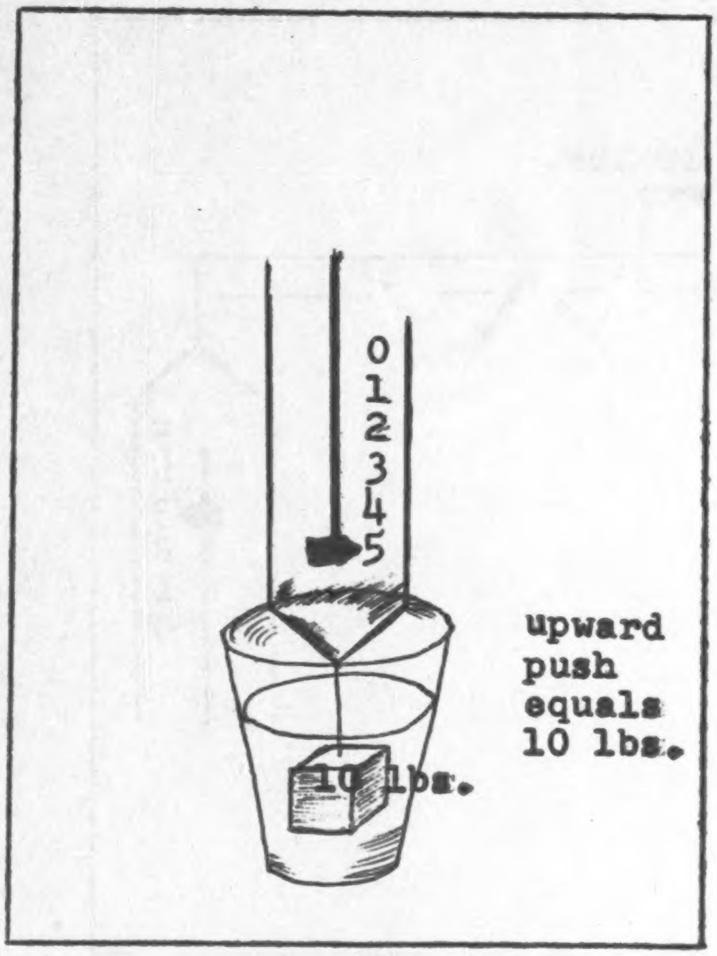

5 4 3 2 1 0 lb
Spring Balance
5 lbs

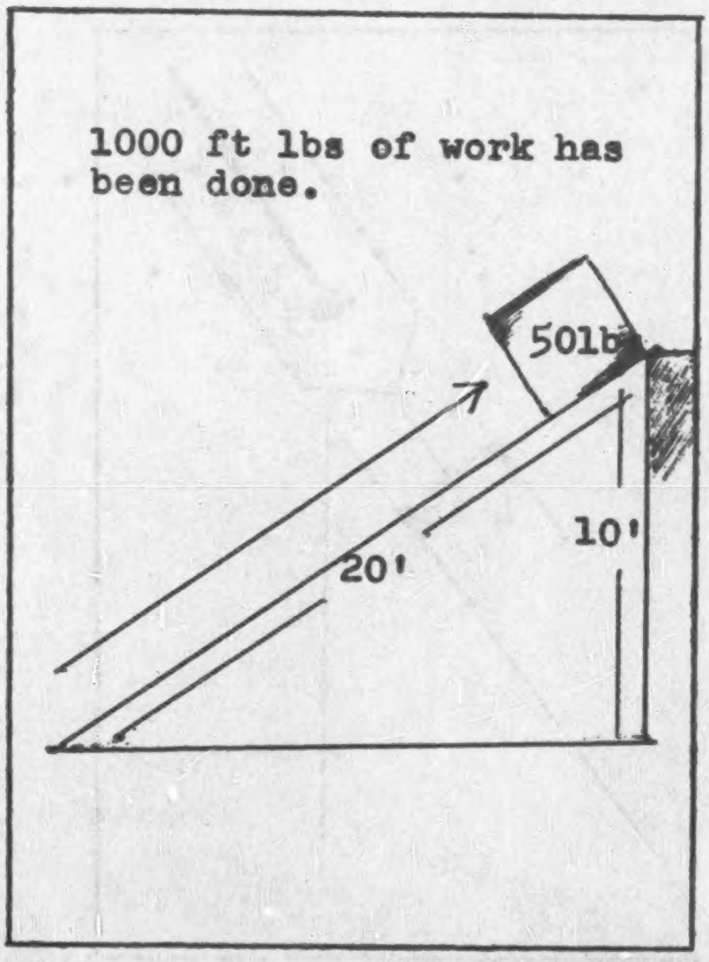

0
1
2
3
4
5
6 lb

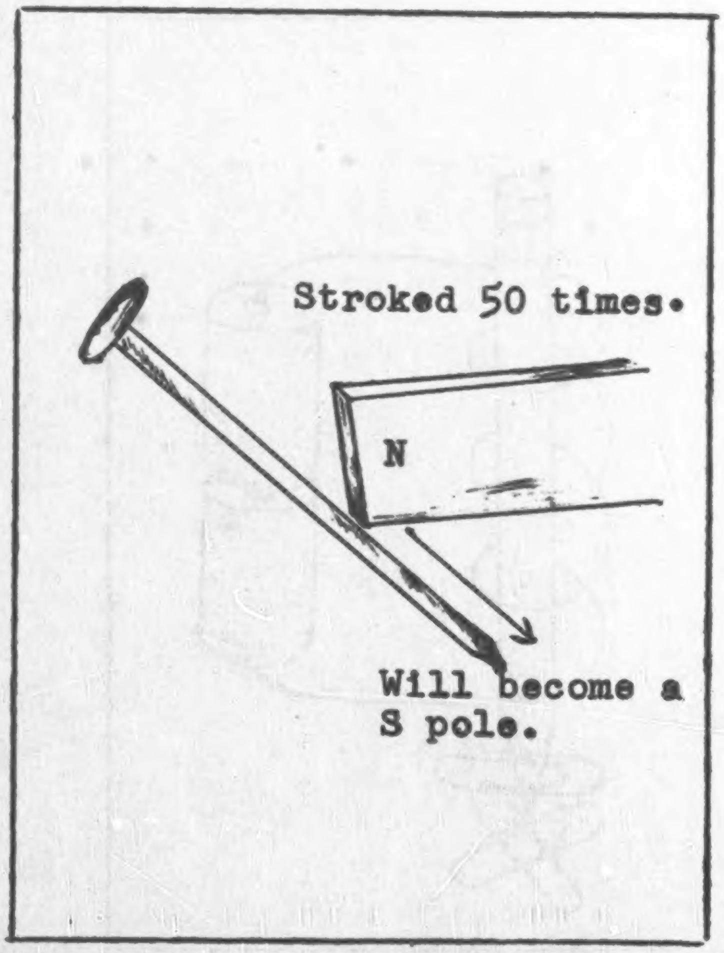

Dry Cell

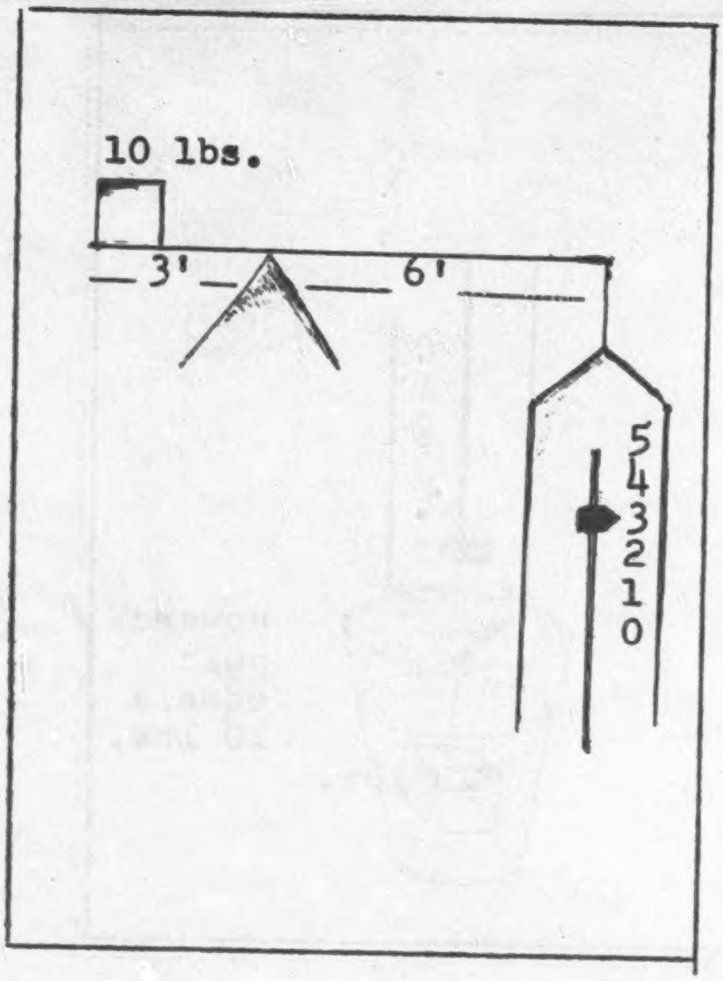


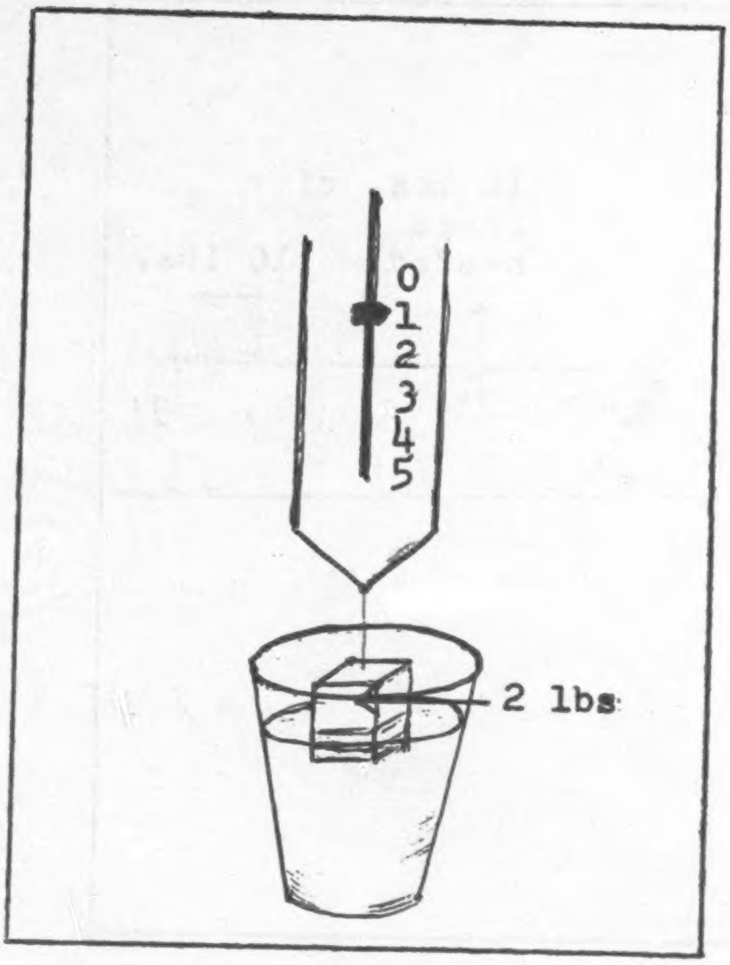

10 lbs. of
force
needed.
10 lbs.
1'
3'

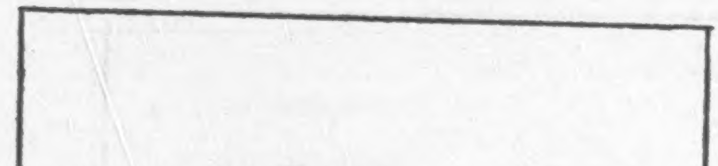

0
1
2
3
4
5
upward
push
equals
10 lbs.
10 lbs.

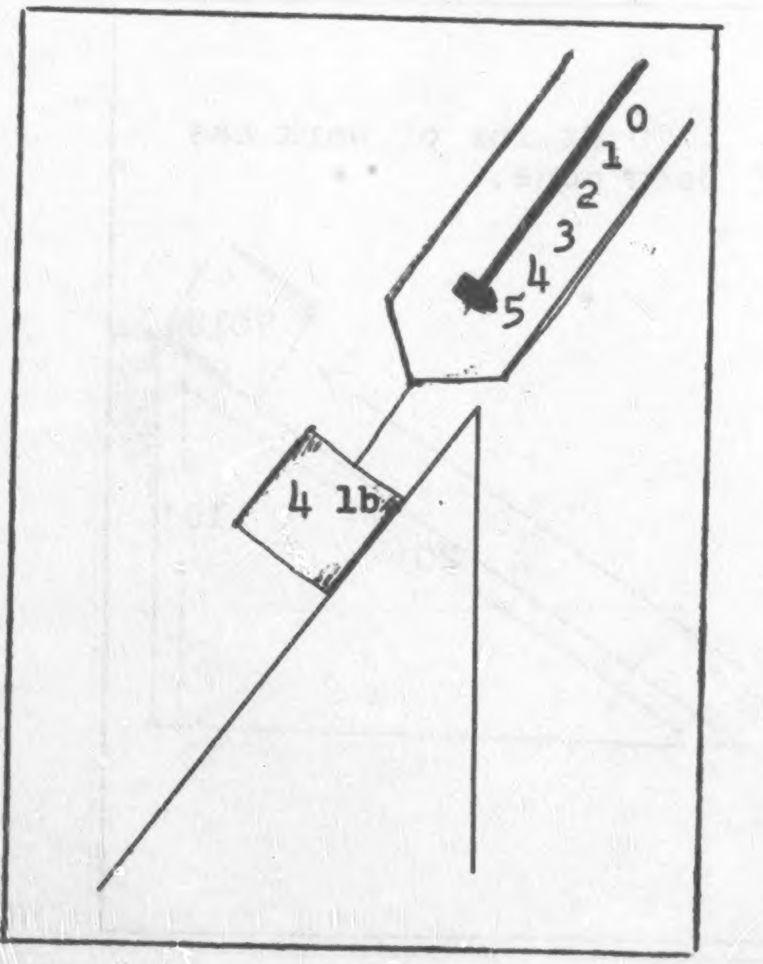

1000 ft lbs of work has
been done.
50lbs
10'
20'

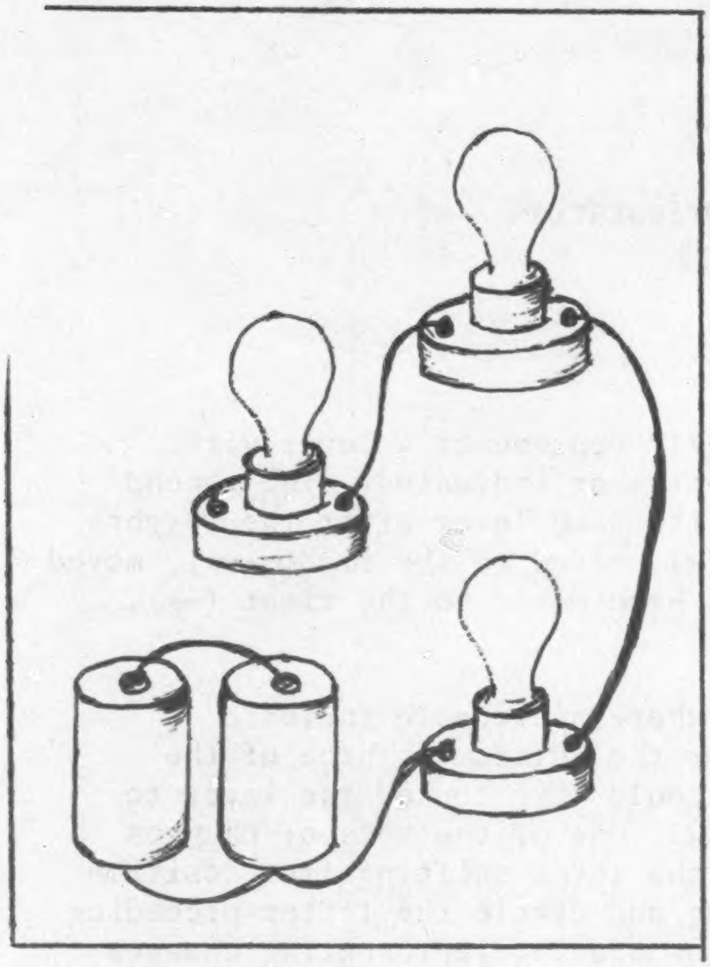

Stroked 50 times.
N
Will become a
S pole.

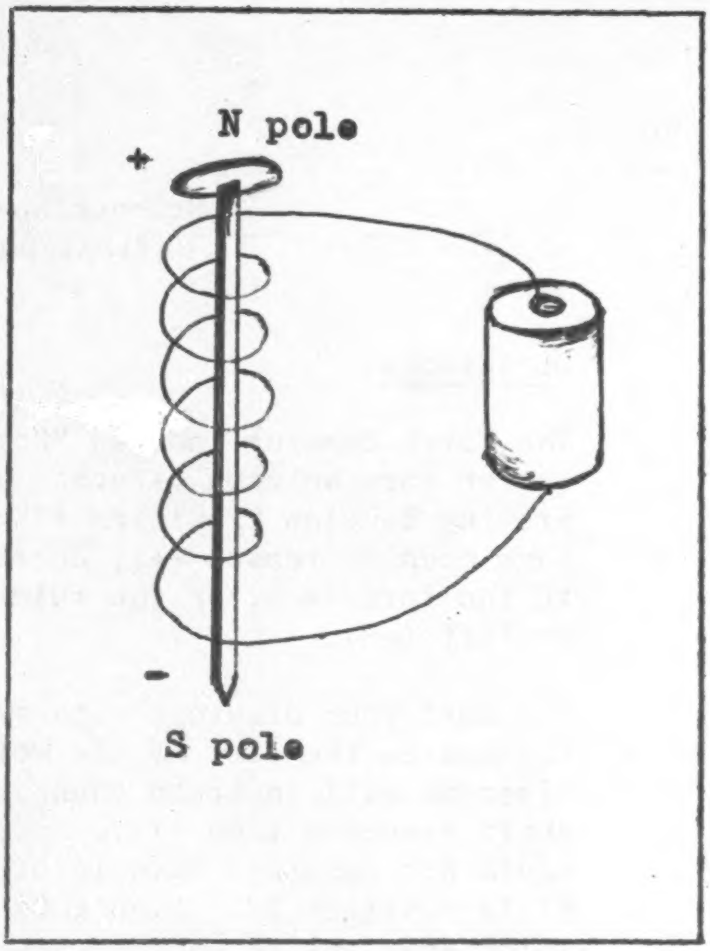

10 lbs.

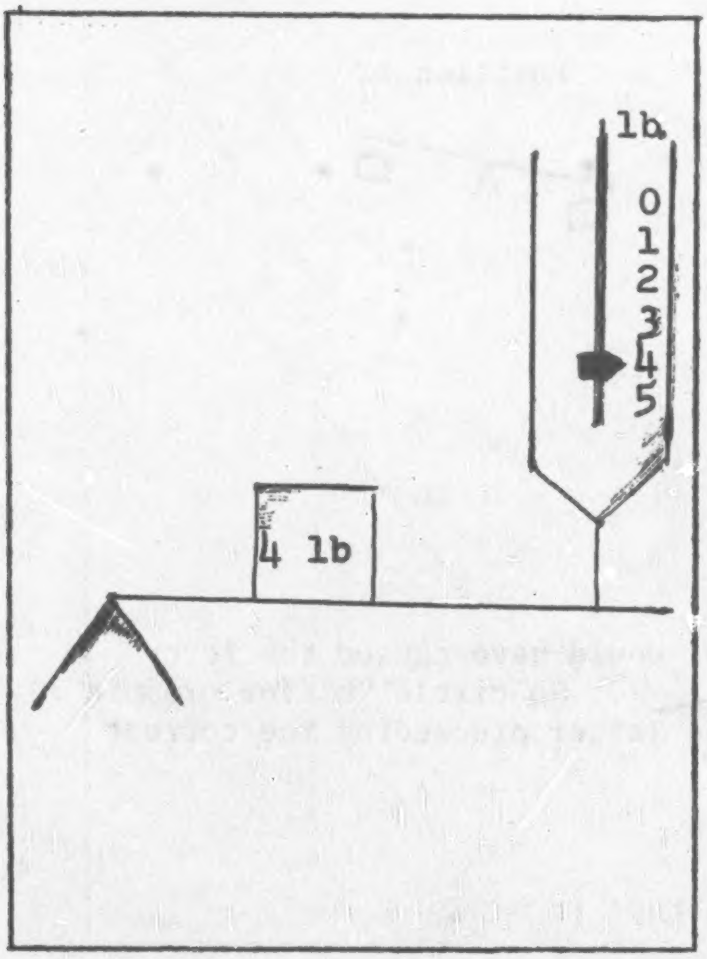

2 lbs

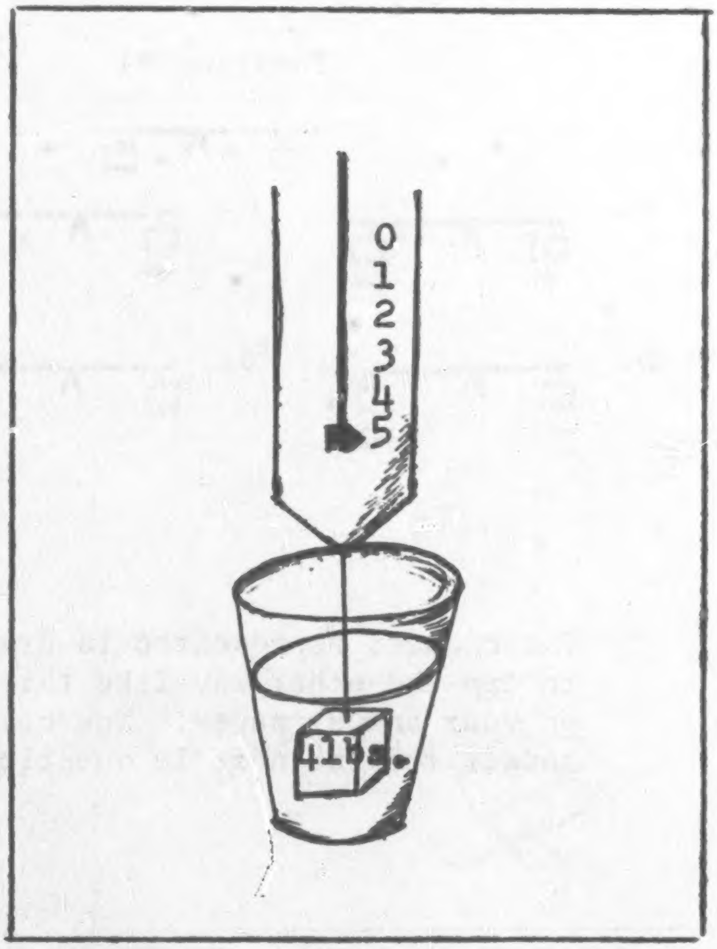



4 lb.




N pole
+
-
S pole


lb.
4 lb


4lbs.

## Science Spatial Orientation
(first page only)
Part I

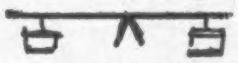
Directions

The first drawing labeled "Position #1" represents a lever with one or more weights attached and fulcrum as indicated. The second drawing labeled "Position #2" shows the same lever after the weights have been increased (+), decreased (-), moved to the right (→), moved to the left (←), or the fulcrum has been moved to the right (→), or left (←).

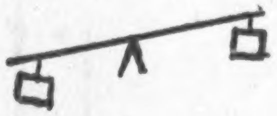
The next four drawings with symbols where applicable indicate changes in the size of the weights or the fulcrum. Three of the diagrams will indicate changes that could have caused the lever to shift from Position #1 to Position #2. One of the sets of changes could not possibly have resulted in the lever shifting from Position #1 to Position #2. Find this drawing and circle the letter preceeding it on your answer paper. Remember the drawing representing changes that could not account for the indicated shift is the correct answer.

EXAMPLE:

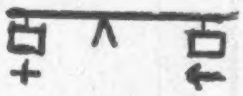
Position #1



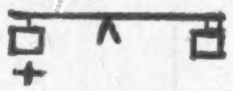
Position #2



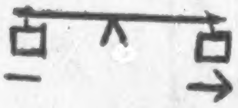
a.



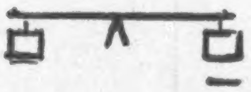
c.

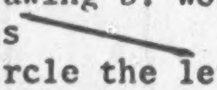


b.

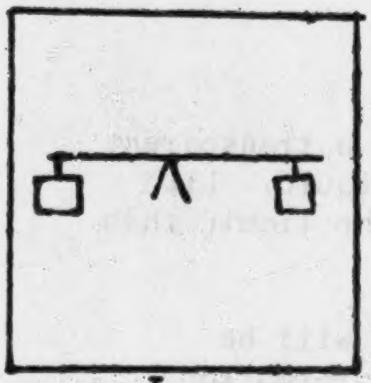


d.



The changes represented in drawing b. would have caused the lever to tip the other way like this  . So circle "b" for example on your answer paper. Now circle the letter preceeding the correct answer for the next 10 questions.

1.



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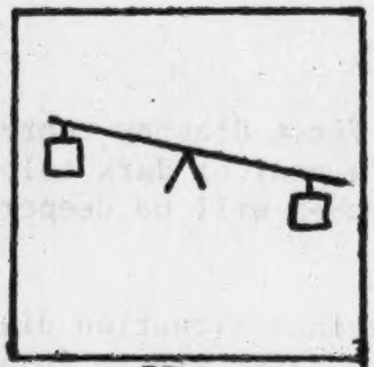

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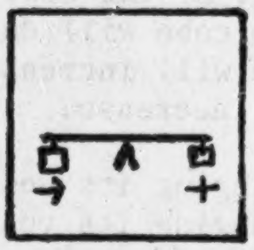

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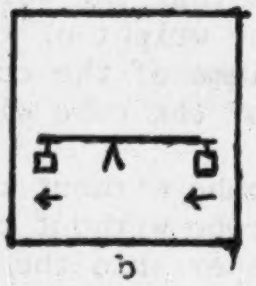

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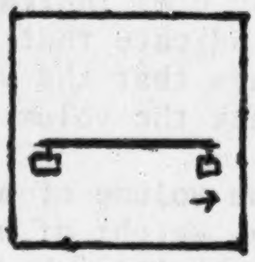

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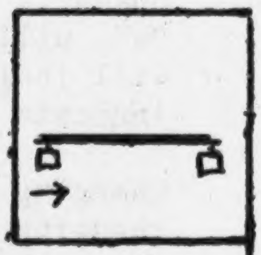

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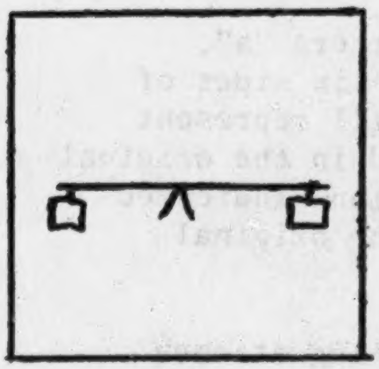

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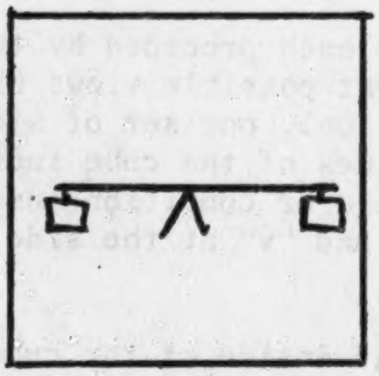

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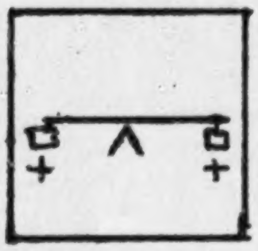

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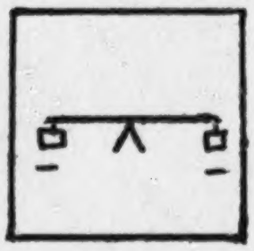

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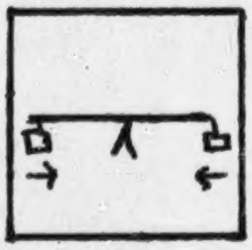

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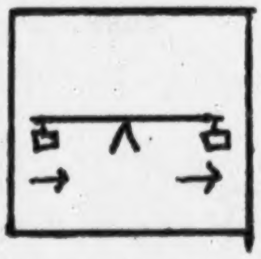

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2

## Science Spatial Orientation
(first page only)
Part II

Directions

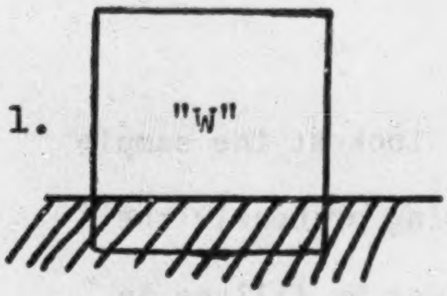
In the following questions the first diagram represents a transparent cube floating like a bottle in a pool of dark colored liquid. Like floating bottles, some of the cubes will be deeper in the liquid than others.

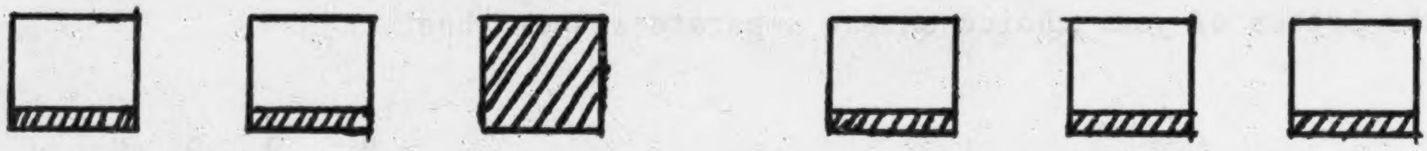
Beside each of the first or original situation diagrams will be lettered "W", "w", "V", or "v". These are to furnish information as to how the nature or condition of that particular cube will change. "W" will indicate that the weight of the cube will increase. "w" will indicate that the weight of the cube will decrease. "V" will indicate that the volume of the cube will increase. "v" will indicate that the volume of the cube will decrease.

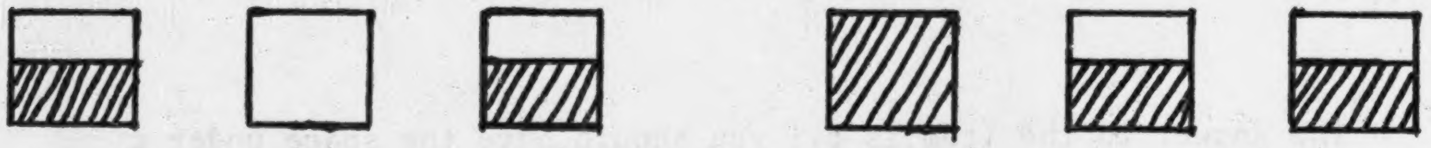
Changing the volume of a cube without changing its weight or changing the weight of a cube without changing its volume, will cause the cube to sink deeper into the liquid or else to float higher in the liquid.

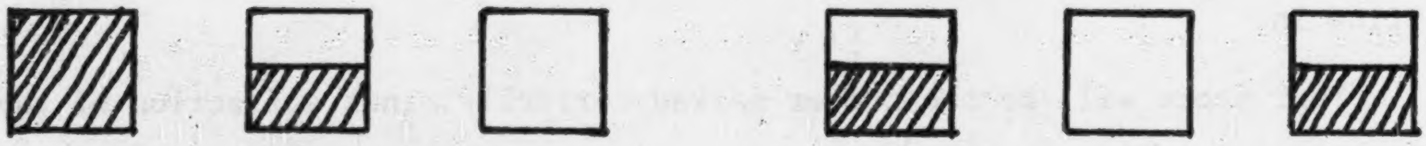
The four groups of six squares each preceded by the letters "a", "b", "c", and "d" will represent possible views of the six sides of the cube as seen from within. Only one set of sides will represent accurately the views of the sides of the cube indicated in the original condition diagram and the change or condition instructions indicated by the letters "W", "w", "V", and "v" at the side of the original condition diagram.

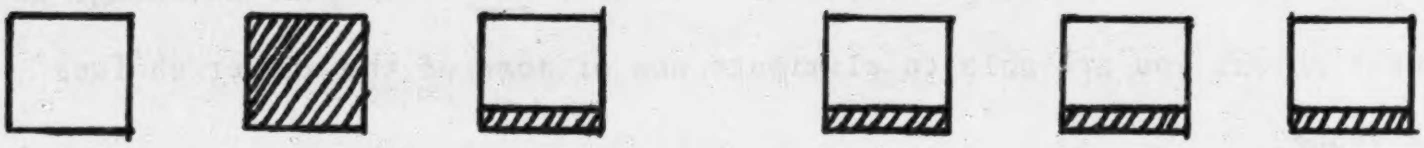
Your job is to imagine yourself inside of the cube looking at each of the six sides. You are to choose the group of six sides that would represent correctly the possible six views in each particular case.

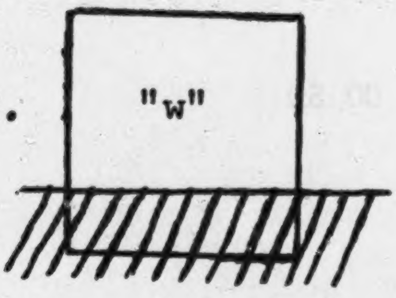
1. 

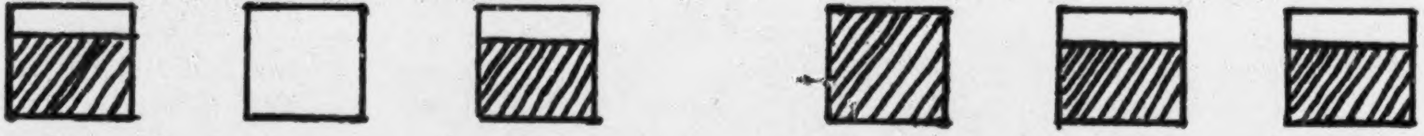
a) 

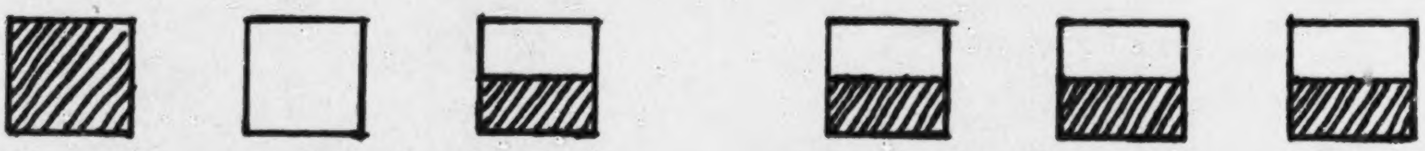
b) 

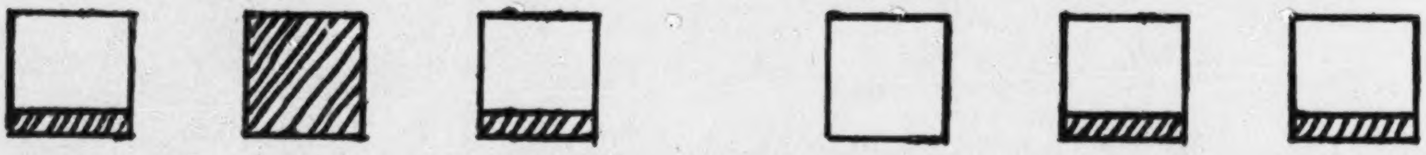
c) 

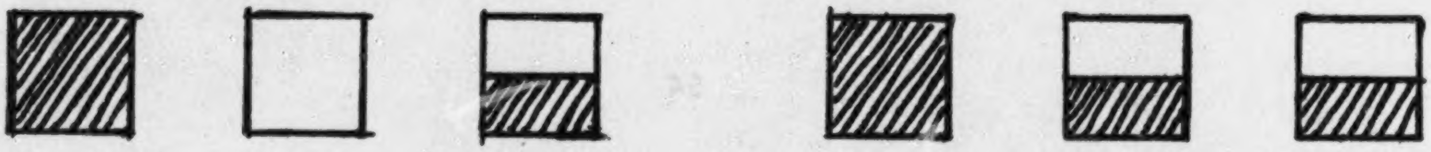
d) 

2. 

a) 

b) 

c) 

d) 

## Science Vocabulary

This is a test of your knowledge of word meanings. Look at the sample below. One of the four numbered words has the same meaning or nearly the same meaning as the word at the left. Indicate your answer by filling in the letter of your choice on the separate answer sheet.

attempt: a. run b. hate c. try d. stop

a b c d
/ / / / // //

The answer to the item is c.; you should have the space under c filled in.

Your score will be the number marked correctly minus a fraction of the number marked incorrectly. Therefore, it will not be to your advantage to guess unless you are able to eliminate one or more of the answer choices as wrong.

You will have 10 minutes for this test.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

1. POTENTIAL ENERGY: a. light energy b. energy of position c. power d. energy of motion

2. CONDUCTOR: a. insulator b. metallic substance c. water d. carrier

3. INSULATE: a. rubber b. cover c. protect from contact d. isolate

4. CURRENT: a. flow b. path c. voltage d. static

5. CIRCUIT: a. flow b. path c. carrier d. resistance

6. RADIANT ENERGY: a. convection b. light c. electricity d. magnetism

7. FRICTION: a. force of attraction b. force of opposition c. inefficient d. moving object

8. FORCE: a. power b. work c. push d. energy

9. VIBRATION: a. source of sound b. notor c. tuning fork d. irregular movement

10. RESISTANCE: a. that which increases b. that which stops c. that which reverses d. that which opposes

11. DISPLACE: a. withdraw b. remove c. advance d. take the place of

12. MAGNET: a. iron bar b. force c. source of forces d. earth

13. PRESSURE: a. weight b. strength c. gravity d. force per unit area

14. MECHANICAL ADVANTAGE a. increases work b. decreases work c. makes work easier or faster

15. FREQUENCY: a. pitch of sound b. loudness of sound c. speed of sound d. quality of sound

16. KINETIC ENERGY: a. position b. motion c. height d. direction

17. LEVER: a. mechanical advantage b. efficient c. fulcrum d. simple machine

18. COIL: a. magnet b. roll c. strand d. length

19. ENERGY: a. power b. ability to work c. push d. strength

20. FULCRUM a. support b. rigid bar c. resistance d. force

21. EFFICIENT: a. effective b. lever c. machine d. advantage

## Seeing Science Deficiencies

This is a test of your ability to discover what is wrong with a proposed plan. You will be given a number of short descriptions of plans or activities that for some reason will not lead to the desired result. You are to then point out in what way the plan is faulty.

Here is an example:

A growing city discovers pressing needs to improve its streets and its sewer system. After due consideration, the council decides to work on the street-improvement program first. What is wrong with the plan?

The streets will have to be torn up again for the sewer system.

As you can see, improving the streets before the sewer system would require the street improvement job be done twice. One way of writing a satisfactory answer is shown in the lines of the example above. Notice that you are not required to suggest another plan, but only to indicate what is wrong with the plan as described. You should be specific; include enough details to make your answer clear and to the point.

Each of the plans in the test contains a planning error that prevents the goal from being achieved or so interferes as to make the plan inefficient or unusable.

Read each description of a plan, then write the main deficiency you see in the plan, using the lines provided on the answer sheet.

You will have 20 minutes to complete this test. Are there any questions?

1. In attempting to lift a heavy barrel onto a 5' platform, John decides that an inclined plane would effectively aid him in doing the job. After extensive searching, he finially finds a sturdy 10' plank that he can use for the inclined plane. Deciding that it is too long, he cuts it in half.

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2. Bill wants to increase the brightness of a small lamp he is using as a signal light and decides he can do it by adding another dry cell to the circuit. He obtains two short pieces of wire and plans to add the cell by means of parallel wiring.

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3. Harry wants to construct an electromagnet so he goes to the hardware store to get some wire, a nail and a dry cell. In making the electromagnet, Harry does not plan to remove insulation from the ends of the wire because the wire is uninsulated. He plans to proceed immediately to the task of carefully winding twenty turns of wire around the nail and attaching one free end of the wire to the negative terminal of the dry cell and the other end to the positive terminal of the dry cell. By holding the wires in direct contact with the dry cell,terminals, he will be able to operate the electromagnet.

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4. In using a second class lever where the weight is located between the fulcrum and the effort, Bill finds that it requires too much work to lift a very heavy boulder. He decides that he can either shift the lever so the boulder is closer to the effort or find a longer lever. There happens to be a stiff bar nearby that is somewhat longer than the one he is using. By changing levers, he thinks he will be able to move the boulder.

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5. Mike learns that the mechanical advantage of a screw type jack is 20. He figures that he is capable of applying a force of 50 pounds to the handle and therefore the jack will be enough to lift a 2,000 pound box high enough so that rollers may then be placed under it. The rollers will then aid in moving the large box across a level surface.

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6. Mary has two egg beaters. The gear to which the handle is attached on one egg beater is twice as large as the gear on the other egg beater. Mary finds that using the beater with the smaller gear allows her to whip cream more rapidly. She then decided that this same egg beater would be easier to use when mixing up a thick, heavy cake batter.

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7. Andy is going to add six 2 volt lamps to a train layout in his basement. He wants the circuit to operate so that if one light burns out, the rest will remain lighted. To do this he will need a 12 volt dry cell, six short, and one long piece of wire to attach the lamps together in a series circuit.

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8. John wants to find the volume of an irregular shaped block. He finds that if he places the floating block in a container of water, the amount of water displaced will be equal to the weight of the block. He thinks that he can find the answer to his problem by measuring the displaced water. He is able to measure the displaced water by finding how much change there is in the water level before and after the block has been added.

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9. In constructing a toy banjo, Susan plans to attach a flat, narrow strip of wood to an empty cigar box, from which the cover has been removed. She then obtains several similar rubber bands to use as strings on the banjo. She stretches the rubber bands across the opening over the box and fastens them to the end of the strip of wood, furthest from the box. She makes sure that the rubber bands are stretched uniformly to get the different sounds needed on the banjo.

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10. Mr. Roberts decides for decorative reasons that he will place the doorknob of his heavy front door in the center of the door rather than on the side away from the hinges.

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11. One side of a tuning fork has been damaged so that its pitch is lower than it should be. Paul thinks he can bring it up to proper pitch by adding solder to the one tine of the fork that has been damaged.

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**12. Bob learns in school that the longer a broom handle is, the greater is the effort needed to sweep with it. He decides to cut 2 feet from the handle of the brooms at home to make his mother's work easier.**

**]3. A man is repainting a boat that he has used for fresh water fishing. He plans to use it for deep sea fishing the following year. With this in mind, he paints the water line stripe above the old one because he expects the boat to sink deeper into the salt water of the ocean than it did into the fresh water of the lake.**

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